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PRIESTLEY'S DISCOVERY OF OXYGEN GAS.[1]

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ANIMAL instincts, when properly considered, are often found to be connected with physical laws. Even in the case of man, his gratifications and dislikes frequently originate in the imperceptible action of external circumstances, and those feelings, and the impulses to which they give rise, are, in the scheme of Nature, strangely bound up with other things, with which, at first sight, they seem to have no kind of connection.

Thus, with what pleasure the whole animal world rejoices at the coming of spring! There is a heart-felt delight, not limited to the higher races, but common to all. With the returning temperature, birds, and beasts, and insects, prepare for the duties of a new year, and every thing seems full of animation and life. Even the illiterate man cannot look unmoved on the green tint stealing over the fields. Perhaps his sentiments may in some measure be connected with a perception that there is a promise for the gratification of his baser animal appetites, and that this prosperous beginning will end in the production of corn and wine for his use. But, behind these, which are the more obvious, there are other causes for rejoicing—causes which can only be fully appreciated by the intelligent, and which have been made plain only by the advances of the highest branches of human knowledge.

How often is our admiration aroused by the work of mechanical artists!—the steamship, which day after day has continued its unceasing and successful struggles with the waves, or the chronometer, which, once wound up, keeps on for months together its regulated motion. Yet how far are all these contrivances outdone in the mechanism of every living man! Of his double nervous system, one part, the intellectual, observes its mysterious periodicities, its time of activity and time

[1] A Lecture; see Sketch of Priestley in present number.

of repose, its time of wakefulness and time of sleep; the other never sleeps till death, but keeps up its incessant action; the beating of the heart, the introduction of air by breathing, involving millions of movements which never fatigue us, and of which we are indeed, for the most part, unconscious. And, now, who would suppose that these, the highest and noblest results of a far greater mechanician than man, are ultimately connected with the return of the spring; and that, in fact, the continuance of the life of man is indissolubly linked with the putting forth of the buds of a tree?

Yet so it is; and surely we cannot spend an hour more profitably than in tracing that connection. Such studies are appropriate to all intelligent men. And, when another spring visits us, we shall not find that this hour has been entirely lost. The reflections it may suggest will, perhaps, increase the pleasure with which we view the return of that great natural phenomenon.

In thus explaining to you the connection subsisting between the animal and vegetable kingdoms, I shall have, in the first place, to introduce an account of the great scientific discovery of the last century—the discovery of oxygen gas—an event rivaling in importance the establishment of the doctrine of universal gravitation by Sir Isaac Newton, in the preceding age.

Until the middle of the last century an opinion universally prevailed that the atmospheric air is a perfectly homogeneous and undecomposable body—that there is but one kind of air, that which we breathe, and though in mines, wells, and other deep and solitary places, substances somewhat analogous occur, they are in reality nothing more than vitiated forms of atmospheric air, which has gathered poisonous qualities from mineral exhalations. From the remotest times these opinions had prevailed. Many of the Greek philosophers looked upon the Olympian Jupiter as only an emblem of the atmosphere, and little suspected that the day would come when that great god of antiquity would be anatomized, dissected, and his various parts and qualities displayed. How often do things which have struck one generation with awe become commonplace affairs in another!

It so happened that, though, from time to time, after the thirteenth century, different gaseous substances were accidentally encountered, they all possessed the quality of extinguishing the light of a candle, and were therefore incompetent to support combustion, and when breathed were destructive of animal life. The doctrine that these were only vitiated forms of the atmosphere seemed very plausible, and this interpretation was received until the middle of the last century, when the capital discovery was made by Dr. Priestley that the air is not a simple substance, and that there is a great family of analogous bodies, each of the members of which possesses peculiar properties. He completely broke down the ancient doctrine of the elementary nature of the atmosphere.

You can scarcely form an estimate of the immense consequences that followed this discovery. It was found not alone to affect chemistry, properly speaking, it threw a flood of light on every allied science. The chemistry of that day was overthrown. Without any exaggeration, I characterize it as the capital discovery of the last age, rivaling in its importance and in its results the great discovery of the preceding century, universal gravitation, by Newton. Extended by the chemists of England, France, and Germany, it has utterly exploded metaphysical physiology, which, taking its origin in the dark ages, has been the great barrier to the progress of rational medicine. Whoever will take pains to [redacted] with attention the works devoted to the exposition of that ancient system, must be struck with the impenetrable obscurity in which it is enveloped. You turn over page after page, and the more you read the more you become confused. It is a constant putting of words for things, of phrases for facts. Even in the hands of the most powerful writers, metaphysical physiology is essentially unintelligible; but not so with that other physiology which has arisen in our times, all its statements are clear, precise, distinct; it relies on the exact sciences, such as chemistry and natural philosophy, because it is itself exact. The progress of all the departments of human knowledge is often the same. Two thousand years ago the pagans peopled Olympus with many gods; and so in the infancy of medicine the corporeal frame was peopled with many intangible forms—a soul, a mind, a vital power, an instinct, a nervous agent, an aura, and animal spirits without end. But a better knowledge of these things is fast teaching us the eternal truth that, as there is but one God in the heavens, so there is but one spirit in man; a presiding agent that supervises and directs all; that all the acts of life are brought about by the inhalation of atmospheric air; and that every living animal owes its so-called vital properties to the action of air within its system; that there thus arise oxidations and other alterations in the economy, so that not a movement takes place, nor a thought occurs, without contemporaneous structural changes. The introduction of air by breathing is, I say, the fundamental fact in physiology; nay, more, it is the fundamental event in the action of the brain. I rest my opinions not on scientific facts, though they are numerous and irresistible, but I go at once to an authority far beyond all chemists and metaphysicians. In vain the physiologist asks me to deny the combustive influence of air in the body, and affects a fictitious fear of the tendencies of such a doctrine. Shall I not believe the positive declaration of him who is the artificer of these beautiful contrivances?—shall we accuse the Almighty of materialism when he tells us that "he breathed into his nostrils the breath of life, and man became a living soul?"

The circumstances that first direct the mind of a philosopher to discoveries destined to exert an influence over the whole human race cannot fail to be full of interest. So it is in the present case. It hap-

pened that Priestley, who resided near a brewery in the town of Leeds, in England, accidentally observed that the beer during its fermentation in the vats gave forth a remarkable aërial substance. The flame of a lighted stick immersed in it was at once extinguished, and the smoke floating on the top of the stratum showed that it was very heavy, a result which was perfectly confirmed by the observation that, invisible and intangible as it was, this air could be poured from vessel to vessel like water, and in the vats in which it originally occurred it would overflow their edges and descend to the door, along which it would run like a stream, its course being readily tracked by the expedient of putting a lighted stick into it, and observing the extinction of the flame. Moreover, he found that it would dissolve in water, for, if dishes of that liquid were placed where it had access, an agreeably acidulous and sparkling fluid, soda-water, was formed. And that the agent which brought all these results about possessed a physiological potency, was proved by the fatal fact, too often known in such manufactories, that if, by accident it was breathed, death at once took place.

The substance which Priestley thus first encountered was that known to us as carbonic-acid gas; it had already been studied under other circumstances by Black and older chemists. I mention it here because it led Priestley to that long-continued investigation of factitious airs, which was crowned by the great discovery of oxygen gas.

We have seen with what acuteness Priestley detected differences between the gas just mentioned and common air. It is a striking fact, verified over and over again in the history of science, that the most imposing results may be presented to the acutest mind, and their significance and value remain undetected. Priestley, in 1771, having exposed some saltpetre to the fire, disengaged oxygen, experimented with it, and even showed its energetic power of supporting the flame of a candle, and yet the value of these truths entirely escaped him. Three years subsequently he submitted one of the compounds of quicksilver to the force of the sun's rays, converged by a burning-glass, oxygen again escaped, and this time he secured his discovery.

He was not long in recognizing its importance. One after another, as the properties were developed, the value of their consequences was apparent. First, a lighted candle, far from being extinguished, burnt with increased brilliancy, and substances commonly reputed incombustible, such as iron and other metals, were consumed as though they were wood. The doctrine of vitiated airs disappeared at once. Here was a substance possessed of all the chemical energies of the atmosphere, only in an incomparably more intense degree. If there were vitiation at all, the air itself was a vitiated form of this gas. Then, too, he found that it could sustain completely the breathing of animals, and that, in reality, it was absolutely essential to the discharge of that function, a fact which led him to apply to it the epithet "vital air;"

and lastly, that the atmosphere itself, far from being, as the ancients had supposed, a simple homogeneous mass, contained this substance as its active principle, mingled with four times as much of another different body.

Here, before explaining the consequences of this great discovery, and showing the position in which it stands, I may be permitted to spend a moment in relating the melancholy but interesting history of its author. It is a lesson which ought not to be lost. Born the son of a tradesman, who died while he was young, and left him very poor, his early manhood was spent in the useful but tedious duties of a village school-master. His attention being turned to theology, he subsequently became the pastor of a Presbyterian church. We must not impute it to mental weakness, but rather to a pursuit of the truth, that in succession he passed through many phases of religious belief, and four different sects, the Presbyterian, Arminian, Arian, and Unitarian, received him as a votary. This is not the occasion nor the place to explain the causes that led him in this course. It is only for us to judge of so great a man with charity. But, imbued as he was with a deep religious sentiment, and feeling that even the most exalted objects of this life are not to be compared with the importance of another world, he regarded his philosophical pursuits as a very secondary affair, and gave much of his time and talent to controversial theology. He seems to have come to the conclusion that it was incumbent on him to make a religious war. As his biographer says, "Atheists, Deists, Jews, Arians, Quakers, Methodists, Calvinists, Catholics, Episcopalians, had alike to combat him." In more than a hundred volumes which he printed, each of these found an adversary of such force and vigor (and it was impossible with such a man that it could be otherwise), that their ablest theological writers were overmatched. By the established Church of England he came to be regarded with such feelings, that instances occurred in which those who had successfully answered him were rewarded with the highest dignities; a circumstance which gave origin to his remark that he appointed the Bishops of England.

But this was not all. The first French Revolution broke out, and, his ardent mind imbibing with enthusiasm the seductive doctrines of the times, he added to his religious disputes those of a political partisan. As the different sects had in succession stood in fear of him, so now the government took alarm; it knew his philosophical reputation and ability. The story is a sad and short one. A mob assembled round his dwelling, which they committed to the flames; the houses of those who were known to be his friends shared the same fate; he narrowly escaped with his life; and for three days one of the chief cities of the nation was the scene of riot. All his philosophical instruments, most of them constructed by himself, his manuscripts, his library, the fruits of a frugal life, were destroyed; and, eventually

driven from his native country, in his old age he found an asylum in the United States, where Mr. Jefferson, then President, received him with kindness and distinction, and in America he died.

In relating this melancholy but instructive story, we cannot but remark how Priestley forgot that the experience of all nations and of thousands of years has proved the utter impossibility of any one man convincing the whole human race, and converting them all to his views. He shut his eyes to that anarchy of opinion infesting the world, brought on in no small degree by such polemics as those in which he delighted. In an exact science, like chemistry, he could describe some new discovery, and every man in Europe at once admitted its truth. He never realized how different it is in politics and theology. The library of volumes he wrote on these topics has already dropped into that gulf of oblivion which has received all the works of the authors of the early and middle ages, and no man cares to learn what he wrote or what he thought of the matter. But not so with his philosophical labors; they stand out clear and distinct, monuments of the advance of the human mind in knowledge and power during the eighteenth century. His discovery of oxygen gas will last as long as the world endures.

From the life of this remarkable man we may draw a lesson, a lesson which the highest authority, with brief emphasis, has given us—"Study to be quiet, and mind your own business." We here see a great man effecting his own shipwreck on the shoals of politics and controversial theology. To what an eminence might Priestley have attained, if he had limited himself to those objects for which Providence had so well fitted him, and abandoned the vain pursuits in which he delighted, to men of less intellect and force! How is it possible, in our times, for a man to be at once a great philosopher, physician, theologian, politician? He must make his selection of one pursuit and stand by it. Not that I would wish an intelligent man, whose opinions must always control or guide those of a large circle around him, to shut himself up from public affairs of great interest. If he perceives, in those to whom the authority of government is committed, a disposition to jeopardize national interests, and pursue an obvious career of profligacy, let him resist them with whatever influence he has, and give his support to those who are the upholders of the peace, prosperity, and happiness of the nation. I would have him set his face against all social disorganizers, and give no countenance to religious disputants.

In thus freely criticising, for your benefit, a character historic in science, I trust I have not infringed in an unkind spirit on the generous maxim, "Say nothing but good of the dead." I join in the dying exclamation of Crœsus, the King of Lydia: "Judge not of the life of a man until you have witnessed his death." And what can there be more touching, or even more beautiful, than the last scene of

Priestley's life? It dissipates the remembrance of all his disputations and all his errors, and shows us that beneath these there was a deeply pervading and redeeming faith. When his little grandchildren were brought to his bedside to bid him good-night, he uttered his last words: "I go to sleep like you, but we shall wake together, and I hope to eternal happiness."

To return from his life to his discoveries. Priestley soon found that oxygen—I give it the name under which it has subsequently passed—was absolutely essential, in all cases then known, to the support of flame and fire, and that animal life depended on it; that a man, by breathing in a limited space, would soon exhaust it of so much of this gas that suffocation would ensue; that the atmosphere, in reality, is a reservoir of it, from which every thing possessing the attributes of an animal abstracts it. It has been shown by succeeding chemists, to such an extent does this abstraction go, that a single man will each year consume about 800 pounds' weight. Considering, therefore, the enormous amount of animal life, the same respiratory process being common to the minutest insect and the largest quadruped, there must be a constant tendency to alter the constitution of the air, for, in proportion as we take from it oxygen at each inspiration, we restore at each expiration an almost equivalent bulk of carbonic acid—a double change, the removal of a vital element, and the addition of a poisonous gas.

But Priestley also showed that, in artificial atmospheres, such as he made, animal life could not possibly be maintained if there were any great reduction of oxygen, or any great increase of carbonic acid. More recent experiments prove that the most striking physical and moral effects arise when men and animals are made to respire atmospheres of a different constitution—effects such as we witness in the case of chloroform and sulphuric ether—a remarkable discovery, not, as is commonly supposed, of only a year or two back, but made by Berzelius, who, twenty-four years ago, gave the most extraordinary, and in a scientific point of view the most important, instance of the kind yet produced—the instantaneous and deep sleep brought on by the respiration of hydrogen; a fact which, in the recent discussions about the priority of that discovery, has been strangely forgotten. From the effect thus arising when the constitution of the medium we breathe is in any degree disturbed, it necessarily follows that, ever since animal life appeared on this earth, the composition of the air must have been nearly unchanged. But here arises a great and obvious difficulty. If the life of men and animals can only be conducted in such a medium as our atmosphere, and if such extensive changes as I have described are constantly impressed on the air by those beings, how does it come to pass that, after the lapse of a few years, it does not gather a poisonous quality? There must be some agency at work, continually tending to prevent that result. The consideration of what

that agency is introduces us to the second branch of Priestley's discovery.

He had put some mice in a glass containing atmospheric air, closely stopped, and found, as usual, that they died of suffocation as soon as the air became sufficiently impure by their breathing; an absolutely poisonous quality being gradually assumed. But, if a few vegetable leaves, or a small plant, were placed in the glass, and exposed to the sun, in a very short time the poisonous quality disappeared, and the power of supporting animal life was regained. Here, then, was an unexpected result—a discovery that gave a solution to all the difficulty, and which has been verified in its minutest details by more modern experiments. It has revealed the great and interesting fact that plants and animals stand in a relation of antagonism to one another; that whatever changes the one tends to impress on the air, the other undoes; and that, while animals discharge their duty in consequence of their being living and moving things, plants perform theirs under the influence of the light of the sun; for these changes do not go on in the dark.

Let us look at these facts by the aid of modern chemistry, premising that oxygen is an invisible substance, existing in the air, and that carbonic acid arises from its union with carbon. When carbon burns, it is merely uniting with atmospheric oxygen, and the resulting carbonic acid escapes away under an invisible form. So, too, when a man breathes, he draws in oxygen from the air; it is distributed to all parts of his system, and, combining therein with carbon, turns into carbonic acid, which is expelled when he throws out his breath. Every animal, therefore, to use the language of chemistry, is an oxidizing machine, the physical end of its existence being to rob the air of oxygen, and put back, in its stead, carbonic-acid gas.

With plants it is just the reverse. As long as the sun is shining upon them, they take carbonic acid from the air, and, decomposing it by their leaves, they set free its oxygen, which escapes away; its carbon they appropriate. With it they form their various parts, their stems, roots, flowers, seeds; but they do this only so long as the sun shines, and when night or winter comes the process stops.

The animal, therefore, takes from the air oxygen, and turns it into carbonic acid; the plant takes that carbonic acid, and turns it back into oxygen, which has thus discharged the great office of carrying carbon from the bodies of animals, and transferring it to the systems of plants. In what an interesting relation do the two kingdoms, the animal and the vegetable, thus stand to one another, not alone as respects the air in maintaining its constitution uniform by a mutual antagonization, but also as respects their own structures! The elements of which plants are formed have all been derived from the preexisting parts of animals; and the elements of which animals consist, from the preëxisting parts of plants. To the classical scholar, what a

beautiful commentary on the fictitious stories of antiquity are these modern discoveries! He calls to mind the metamorphoses that Ovid describes; the bore, perhaps, of his school-boy life, the elegant amusement of his later years. He remembers how Daphne was turned into a laurel, and Adonis into a flower; the musical stanzas are no longer an empty sound, they are descriptive histories. The thing he has read of is actually so. These transformations, instead of being imaginary exceptions, are the common lot of life in this world. There grows not now a leaf that is not formed from the parts of animals that are dead; there lives not a solitary animal being which has not derived its constituent elements from plants.

Here, then, we are led to a most remarkable conclusion. If the air for thousands of years has remained unchanged, and if these antagonizing processes are all the time going on, equalizing its constitution, it necessarily follows that the amount of vegetable is accurately adjusted to the amount of animal life; the one cannot get the better of the other, for, if it did, the excess would be instantly restrained by its antagonist, and, in this point of view, these two grand forms of life constitute together a splendid automatic or self-adjusting machine. Men talk about the dullness of science; it is only so to those who are unable to follow its developments to their consequences. Where will you find in the whole range of poetry a conception more sublime than this? The two divisions of the world of organization reacting on each other through the medium of the atmosphere—the living against the lifeless, the moving against the motionless; and not only thus influencing each other through that medium, but maintaining its properties forever unimpaired, and ready for action. It is the glory of astronomy to have proved that the planetary orbs, which circle round the sun, under the influences of a pair of forces thus reacting, can retain their movements undisturbed through a coming eternity. And if astronomy has made the splendid discovery that the inorganic world has attained a condition of eternal equilibrium, chemistry has rivaled it by showing that the same grand truth applies to the world of organization. To watch the eternal coming out of the transitory will always strike a reflecting mind with emotions of the highest admiration. The sunbeam—the finger of God—that reaches across the unknown abysses of the universe in a moment, bringing life out of death, and clothing the objects around us with their many-colored dyes, has extracted this condition of everlasting permanence from a preëxisting transient order of things.

From considering this adjustment of the animal and vegetable kingdoms to each other, we might be led to the idea that each individual in these natural divisions has its counterpart in the other; an idea bringing us into a new relation with inanimate objects. There is implanted deeply in the hearts of all men an instinctive love of natural scenery—forests, flowers, the green grass—and surely such a sen-

timent cannot suffer from the thoughts now occurring to us. We establish with such objects a relationship, I had almost said a friendship; they become, as it were, a part of ourselves, things essential to our own existence; and that deep attachment we feel to the place of our birth, or our home, finds its apology not alone in natural instinct, or in acquired habits, but also in the highest philosophical considerations. In imagination we might mark off groups in the two kingdoms which are the fanciful representations or counterparts of each other. Perhaps we men, who have to resist the storms of life, may have our representatives in the rugged trees of the forest; the ladies will certainly find their antagonists among roses and other flowers.

From what has been said, you will have gathered how important is the part which oxygen plays in the scheme of Nature. To it is committed the duty of destroying all animal races, and transferring the parts of which their bodies are composed to plants. It begins to discharge this function the moment we begin to breathe, pervading each instant every part of our bodies, bringing on interstitial death, and the continuous removal of particle after particle which it carries away. For there is an incessant change in the substance of all living structures; that which we are to-day differs from that of yesterday and to-morrow, and this untiring agent is all the time at work, assaulting and undermining, nor stopping its action with our dissolution, but going with us into the tomb, until it has restored every particle back to the air. Death is not, as the popular superstition says, a phantom skeleton, nor, as the Asiatics think, a turbaned horseman, who pays his sudden and unwelcome visits. He is this invisible principle in the air which surrounds us, and which is in the very breath we respire.

If thus the duration of individuals and races is determined by the two great systems of forces which have been combined into a self-acting contrivance, it surely is one of the most interesting inquiries in which we can engage, to find in what way so extraordinary a combination has been established. From those remote periods to which we are able to trace the history of the earth, has the same kind of agency prevailed, or have other laws and other self-acting contrivances been resorted to in other times? You see I here assume the doctrine of the geological antiquity of the earth without any kind of hesitation. During two centuries its spherical form was bitterly denied by many very good and well-meaning men. But the truth at last prevailed. And during the last fifty years its age has in a similar way, and on similar principles, been contested. But this, like the former, is now a settled question; neither the one nor the other is any longer open to debate. He who thinks the earth is only a few thousand years old, simply knows nothing about the matter. He who denies its antiquity will also probably deny its figure.

I proceed, then, rapidly with the inquiry in which we are engaged,

and would premise that there is no fact better established in all the range of physical science than that of Priestley's, heretofore mentioned, that plants grow at the expense of the atmosphere. I further call to mind the indubitable fact that all coal, whether bituminous or anthracite, is of vegetable origin; that all the great deposits of these carbonaceous materials, occurring in Europe, Asia, Africa, America, and in the islands of the sea, for hundreds of miles in extent, and of unknown thickness, are vegetable matters once formed under the influence of the sunlight, and existing as luxuriant forest-growths—forests that in succession were entombed in the bowels of the earth. There was then most assuredly a time when all this carbon existed as carbonic-acid gas in the air, giving rise to an atmosphere in which, as we know, animal life could not exist. But the sun had charge of the matter, and as centuries rolled by he was extracting that poisonous gas from the atmosphere, effecting its decomposition, as he did for Priestley, bringing forth from it vital air, oxygen gas, and getting things ready for the appearance and continuance of animal life.

I therefore regard, in a philosophical point of view, the period of the deposit of the coal as the great event in the earth's history. Those who are familiar with the details of these things will recognize it as the epoch which parts off a blank solitude on one side, broken by the rude beginnings of low animal life, from that later period, on the other, which is adorned by all the beautiful contrivances of animated Nature, and crowned by the presence of man. The laws of Nature have ever from the beginning been such as they are now. We are fully able to trace the clear relationship between the condition of living things on the surface of the earth and the constitution of the atmosphere; and what chemistry says ought to have taken place in successive centuries, geology tells us actually occurred. Understanding the changing condition of things as respects the air, we could predict the corresponding changes in animated Nature, and the evidence that we are right is engraved on the rocks and stamped on the ocean.

So, therefore, we see that that relation which now exists between animals and plants, and the atmosphere, is an affair that has sprung out of a prior order of things—that there was a time when the constitution of the air was utterly unfit for the support of animal life; that a purification took place through the action of the rays of the sun; and the deposit of coal marks out the great epoch when life of a high order, among air-breathing animals, became a possibility. And is it not interesting to remark how gradually, from a totally different order of things, have sprung those great laws which determine not only the fixity of the constitution of the air, but also the duration of species and individuals; that automatic, self-acting machine in which animal and vegetable life are the opposing forces.

In thus sketching out the course of events as we now know them to have taken place in those ancient times, and in explaining how one

system of laws has spontaneously been developed out of another, we cannot avoid making a comparison between the feeble contrivances of men and the means resorted to for the conservation of the world. We are accustomed to look back with admiration to the wisdom of those great men who laid the foundations of this republic, and established a constitution for it; but what would our admiration be if it had been possible for them to have enacted one single law of such simplicity and comprehensiveness, that every other law, by any possibility required in all the contingencies of a thousand years, should have spontaneously sprung out of it? if it had been possible for them, by one legislative act, to have completed and brought to a conclusion all legislation? The good and evil which we constantly see arising in our political assemblies, what are they but commentaries on the want of wisdom and want of power of man? But what is not possible to man is possible to God; and I think it will always elicit from a reflecting mind a tribute of veneration, to know that this great and intricate machine of the universe, with all the millions of beings, living and inanimate, that compose it, with all their affections, attributes, and relations, are sustained and governed according to the original and unvarying intention of their changeless Author; that from the beginning of things, as respects its physical condition, there never has arisen occasion for retouching a work perfect in itself from the first. I am not among those who regard this system of acting through ancient and self-imposed law as in any wise derogatory to the Great First Cause. I appeal to the common decision of mankind, whose admiration of any human contrivance or machine is greater in proportion as the machine is self-acting, performing its effects with rigorous precision, according to the conditions under which it was constructed; but less, if the engineer has from time to time to interfere in order to insure its successful action. I recall that well-known maxim of the law, "Qui facit per alium facit per se"—whoso acts through another, acts himself. It makes no difference in my estimation, in this respect, whether the Architect of the universe himself directly interposed, and compelled such a constitution of the earth's atmosphere as was conducive to the ends he had in view, or whether, under the laws he had imposed on it, the obedient sun proceeded to discharge that task, and put forth his rays with unwonted effulgence, bringing on a great increase in the amount of vegetable life, a great depuration of the atmosphere, the burial of enormous quantities of carbon in the ground, and the gradual assumption by the air of that condition suited to the support of a high organization, and of the life of man. I appeal to the experience of us all—each of the celestial phenomena we witness, the revolutions of the stars, the return of comets, the occurrence of eclipses, each of the changes that happen on earth, the flux of the tides, day and night, summer and winter, the budding of trees and unfolding of flowers, the rise and fall of empires—do they not all take

place, not through present and incessant interventions, but in obedience to ancient law? I recall what we all witness as respects the social condition of man, that, according as he advances in intellect, he lives under self-imposed rules, and that his reverence for law is the measure of his civilization; that it is the pride of that civilization to put in the place of an autocrat, dispensing instant rewards and punishments with his own hands, the ideal majesty of the law, which deals out inflexible justice to the good and evil, and makes no distinction of persons; and, reasoning in this manner, from insignificant beings and small things to those which are great, I conclude that a Pure Intelligence will rarely act by intervention, but always through law.

Through that astronomical agency to which I have referred—the action of light exerted during the period of the deposit of the coal—a purification of the atmosphere was effected to such an extent as gradually to enable warm-blooded animals to exist, the temperature to which they attain being directly dependent on the amount of oxygen they take from the air. All animals, from the first period of their coming into existence to the moment of death, are continually, by their respiratory effort, obtaining this gas, so essential to their very existence, and as continually expelling the effete and dead matters of their systems, under the forms of other airs—carbonic acid, ammonia, and the vapor of water. And thus the atmosphere is the source from which our bodies come, and to which they return, continually during life, and, with the exception of their earthy ingredients, totally after death, and the gases that are found in it are at once the agents and objects of the change. Had Priestley realized these things, could he have induced Chemistry by her witchcraft to compel the gas he had discovered to tell its own story, and how it determined his destiny, his imaginative but theological mind would perhaps have recalled the similarity of its own adventurous inquiry with that of the old Jewish king who visited the sorceress at Endor. Awakened by the power of her spell, there arose, from the enchanted circle over which she waved her wand, the form of an old man whose face was shrouded in his mantle. And he said, "Why hast thou disquieted me, to bring me up? To-morrow shalt thou and thy sons be with me."

Some seek for pleasure in the mere gratification of animal appetites, let us rather find it in the exercise of the intellect; and, when spring approaches, let us rejoice in the change, not so much because there is a promise of food, though we should never forget that all these vegetable products, of which so many are destined to delight our tastes, were mortal poisons while they were yet in the air, but chiefly because they are indications that all that is necessary for us as thinking beings is accomplishing. I have told you that the continuance of the life of man is indissolubly linked with the putting forth of the buds of trees. Let the one fail, and the other will speedily stop. Nay, more; as all our intellectual acts can only go on as a consequence of respiration, and

the respiration, too, of such an atmosphere as that of our earth, we perceive that our highest endowments are thus connected with things at first sight apparently having no connection with them. And though it is thus the arch-chemist, the Sun, who transmutes a poisonous gas in the air into fruits, and seeds, and flowers; who prepares the vital medium that we breathe, and enables us, therefore, to think and move, shall we not look with veneration, through his more obvious agency, to a silent influence that is beyond? For these products of his action are so many witnesses to us of a provident foresight for our physical and moral wants. There is an authority who has taught us not to disregard such natural emblems. Who is it that has set his rainbow in the cloud, as the pledge of a plighted word? We are surrounded on all sides with similar indications, and are constantly invited to see in each material event a token of intellectual benefit; and if, as we have seen, from a poisonous atmosphere, there has thus gradually been developed, under the agency of that great celestial body, a medium suited to the well-being and conducive to the happiness of man, may we not hope that what has taken place as respects his physical is a type of what will occur as respects his social condition. Who that looks on the events which this year has brought forth[1] —the overturning of thrones and time-cemented institutions, the bloodshed and atrocities of civil wars—who does not recognize that we are entering on an era? The material atmosphere once had a poisonous constitution, the social atmosphere has its poisons too. There is a cry, almost of despair, from the Baltic to the Mediterranean, from the Black to the Atlantic Seas. It is no imaginary nightmare that is oppressing men, but so greatly has the human mind been developed by the advance of knowledge, that it has outgrown the existing order of things. The pressure of that invisible social atmosphere has become too intolerable to be borne; it must be cleared of its impurities and poisons; there must be freedom for thought and freedom of action. The natural change which we have been considering was only brought about after many a convulsion; the moral change must have its catastrophes. But are we not taught, from this evening's reflections, to trust that there is in this too the influence of One far greater than the sun, but of whom the sun is the most noble and appropriate type, who, unaffected by the tempests of the times and the sufferings of men, is steadily shaping the course of events, to bring things at last into a condition suitable for the intellectual as well as the physical well-being of our race?

[1] This was said in 1848, a year of many political revolutions.

THE PHYSICS OF ICE.

By E. LEWIS, Jr.

THREE-QUARTERS of a century ago a cargo of ice was obtained from a pond near the junction of Broadway and Canal Street, in New York, and sent to Charleston, South Carolina, in a vessel chartered by a gentleman of that city. But it was in 1805–'6 that Frederick Tudor, of Boston, inaugurated and laid the foundation of the now immense ice-trade of the United States by shipping, as a mercantile adventure, a cargo to St. Pierre, on the island of Martinique. This cargo, with several subsequent shipments to other West Indian ports, was largely unprofitable. The people to whom it was sent, unfamiliar with its use, knew little of its value.

In 1833, Mr. Tudor sent in the ship Tuscany the first cargo of ice from this country to Calcutta, and thus began the ice-trade of the United States with seaports of India. Several years after that event, the Hon. Edward Everett, then our minister to England, met in London a wealthy and eminent Hindoo, who cordially thanked the American people whom he represented for the great service they had done to his countrymen in shipping cargoes of ice to India. It is obvious that, in our zone of alternate heat and cold, ice is one of Winter's great benefactions. In the healthy preservation of food it is indispensable during summer's heat. In regions where little ice forms, the mountain-snows are economized. Some years since the supply on Mount Etna gave out, and a glacier buried beneath sand and lava was found, and worked as an ice-quarry to supply the necessities of the people. Ice of good quality is now produced by artificial methods, but it is our purpose to develop in this paper some of the physical properties and phenomena of ice, rather than its economic value.

Ice is simply water in a solid state. In ordinary conditions it begins to form at a temperature of 32° of Fahrenheit's thermometer, and this is the well-known freezing-point. Below it the molecules of water become fixed in the grasp of molecular force; above it they are separated by heat, and fall asunder, forming liquid water. But to this law are exceptions, in which water may be cooled many degrees below 32°, still remaining liquid. In glass vessels exposed in open air, water kept perfectly still has been reduced in temperature 15° below freezing, and in a vacuum much lower than this. In this condition there is a "tendency to freeze which is kept in check only by the difficulty of making a commencement," and the process begins by the slightest jar of the water. Fine particles of vapor, or mist, and water in fine capillary tubes, may remain unfrozen 20° or more below the freezing-point. Water thus cooled rises in temperature the instant crystallization begins, by liberation of its heat, and at 32°

becomes solid. But, ice may be chilled to any attainable degree of cold. Prof. Tyndall reduced its temperature 100°, during which process it shrank in volume and became intensely hard. From the blow of a hammer it broke with a vitreous ring.

We often witness the fact that water will not freeze if in rapid motion, although it be much colder than the freezing-point; but in this case will freeze at the bottom where its motion is retarded, forming what is called "ground, or anchor ice." The sandy bottom beneath swiftly-flowing streams is sometimes frozen solid by radiation of its heat to the cold water flowing over it. But no ice will form at the bottom of a pond or lake if the water be at rest; it then forms upon the surface only. The particles of water, as they become chilled to near the freezing-point, expand, become lighter, and continually rise to the surface, where they solidify, forming a roof of ice. This phenomenon opens a most interesting chapter of physical science, and we will presently recur to it.

The freezing-point of water may be changed by pressure, that is, water under pressure will not solidify at a temperature of 32°; nor is it known how great a degree of cold it can resist if a corresponding degree of pressure be brought to bear upon it. The lowering of the freezing-point of water by pressure is one-seventieth of a degree Fahr. for a whole atmosphere. Under a pressure of several thousand atmospheres, ice has been liquefied at or near the temperature of zero; so

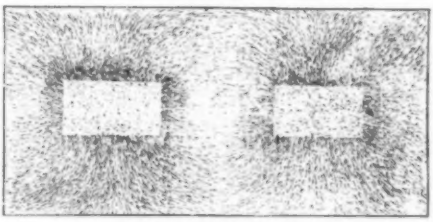
FIG. 1.

LIQUID PLANES IN ICE FROM PRESSURE.

that the freezing-point was zero, instead of 32°. The tendency of pressure is, therefore, to keep water liquid, and to render it so after being frozen. The effect of pressure on a cube of transparent ice is well shown in Fig. 1. It is no longer transparent, but is traversed by hazy lines which come into view as the strain is applied. These hazy

lines are portions which have become liquid. We have seen that freezing is a process in which water expands in volume. This implies change in its molecular structure, or that the molecules assume new positions. Perhaps the wonderful movement of particles around the poles of a magnet, illustrated by Fig. 2, may suggest the nature of the interior movements which occur in the crystallization of water. Certain it is that the molecules recede from each other and occupy more space than when they lay compacted in the liquid condition.

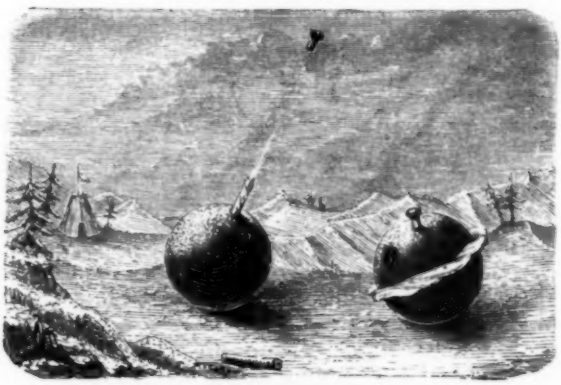
FIG. 2.



MAGNETIC CURVES.

Water expands, in freezing, with a force that is practically irresistible, its increase in volume being about ten per cent. Flasks of copper and iron are broken by it. Rocks are split asunder and disintegrated, and from this cause the freezing of water plays an important part in geological changes. A bomb-shell filled with water and closed by an iron stopper was exposed to frost; in a little time the stopper

FIG. 3.



EXPERIMENTS, SHOWING FORCE OF EXPANSION.

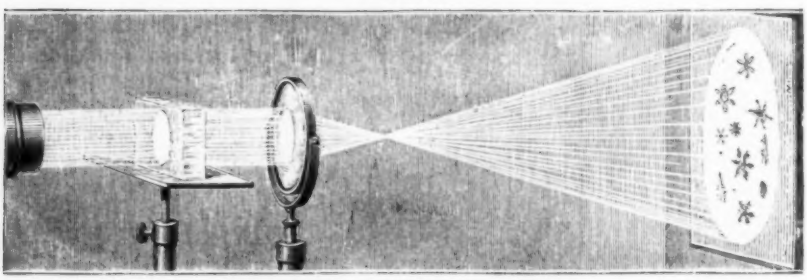
was driven out to a distance of several hundred feet, and a mass of ice protruded. In another case the shell burst, and a sheet of ice expanded around the crevice. These tremendous mechanical effects are shown in Fig. 3. In these and similar cases the water may not have

been solidified, the tendency to freeze being held in check by pressure, but occurred the instant the pressure diminished.

The expansion of water at freezing is vastly important in its relations to life. Without this property, water in high latitudes would become permanently solid, and the aspect of Nature be one of lifeless desolation. Water, in cooling from a high temperature, contracts in volume, and the cooled particles sink until the mass is reduced throughout to a temperature about seven degrees above the freezing-point, when an important change takes place. Contraction of volume ceases, and expansion begins. The chilled particles remain at the surface from their lightness, and there solidify, while the water beneath, in its deeper portions, may be 7° warmer than the point of freezing. By this means a temperature of water in lakes is maintained adequate to the wants of life.

The structure of ice is crystalline, and the fundamental pattern of the crystals is six-rayed stars. But it is only in entire freedom of molecular motion that crystals attain perfection of symmetry. They form upon the surface of water, when the cold is severe, with great rapidity; but are modified in their arrangement or aggregation the instant the first crust is produced. The additions to the thickness of the ice are always at its underside, and the result is a prismatic form,

FIG. 4.

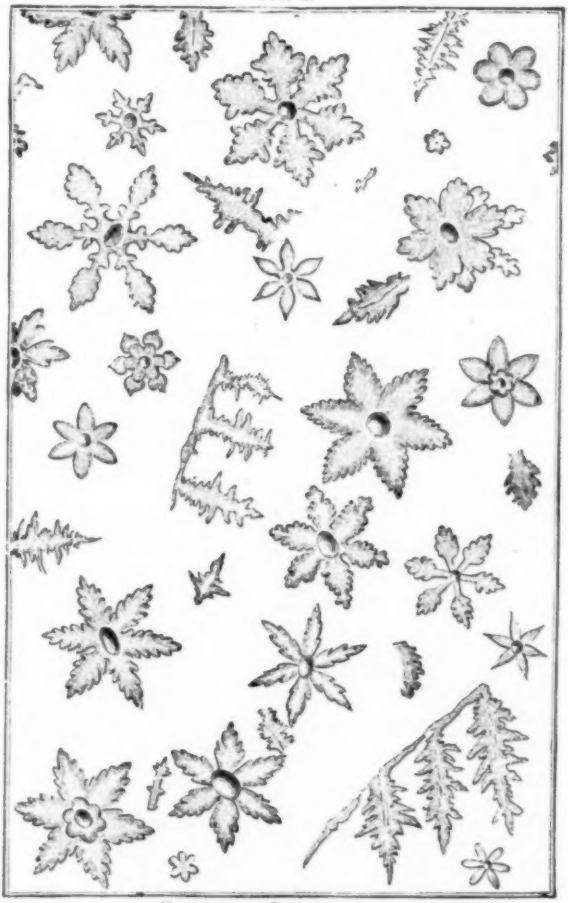


FLOWERS OF ICE PROJECTED ON A SCREEN.

the prisms growing downward. These prisms are hexagonal in shape, and are so joined at their sides as to present an apparently homogeneous structure. That such is not the case, however, will be seen when we speak of the decay of ice. That the internal structure of ice is upon the stellate type is shown when a small cube of it is dissected by a beam of light. By the heat rays of the beam, the ice is decrystallized—its molecular architecture is taken down, and the result appears in stellate figures of exquisite beauty upon the screen. These figures are areas in the ice which have been liquefied by the beam, which thus throws on the screen an "image of its own work." In Fig. 5 we have magnified pictures of the crystalline structure of ice. They seem shadows of living objects, rivaling fern-leaf and blossom in

delicacy and fairy-like beauty. Prof. Tyndall, the great classic on this subject, says, with reason, that, "in the estimation of science, ice bears the same relation to glass that an oratorio of Handel does to the cries of a market-place. The ice is order; the glass is confusion. . . . Nature lays her beams in music." In each complete flower is a little

FIG. 5.



FLOWERS OF ICE MAGNIFIED.

disk. These are vacuous spots, caused by diminution of volume as the ice is converted to water at each point where a flower is produced.

Ice-structure is not impaired by the luminous rays of a beam, to which it is transparent, but by the dark or heat rays, to which it is opaque. These, arrested in their transition through it, expend their energy in taking asunder the molecules of which it is constructed. They become "our working anatomist," and reveal the interior and otherwise hidden form of ice architecture, shown in the ice-flowers of the figure.

Had the heat-rays which destroyed the ice fallen into water, it would have been heated; but, falling into the cube of ice, and melting a portion of it, no change in temperature occurred. Ice melts at 32°, and the temperature of the water in which it floats is kept steadily at that point until all of it has disappeared. The ices we consume, and the iced drinks for which we thirst in summer, are, at the freezing temperature, 68° colder than the internal organs with which they are brought into contact.

Ice, like other solids, may be cooled and warmed. That which Tyndall chilled 100° could be warmed steadily to the temperature of 32°, and a thermometer would indicate the change; but at that point the process is interrupted—the structure falls into pieces, and not until the mass is entirely liquid can the warming be resumed. From that point, however, it goes on until, at a temperature of 212°, it again ceases, and the molecules of water are separated into vapor.

But, in melting the ice by the dark or heat rays of the beam of light, a great quantity of heat was consumed, not in raising temperature, but in undoing what molecular force had done. To simply melt a pound of ice requires 142° of heat, that is, an amount which would raise the temperature of a pound of water 142°. Now, this is the equivalent of the molecular force exerted in solidifying the water, and the mechanical value of the two forces is the same. Expressed in figures, it is equal to lifting the same pound of ice 110,000 feet high. The mere melting of 20 pounds of ice, a quantity received daily by many families, is equivalent, in mechanical force, to lifting nearly 1,000 tons' weight a foot high, or to lifting two persons weighing 300 pounds 1,000 feet higher than the summit of Mount Washington. We may thus realize the enormous display of energy along the line where heat and molecular force contend for the mastery.

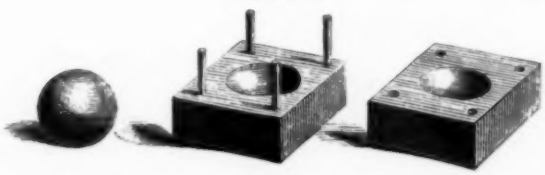
The transition of water to ice, and of ice to water, produces important changes in the temperature of surrounding objects. We are often made painfully sensible of the chilling influence of the atmosphere when its heat is rapidly abstracted in the melting of large masses of ice and snow. But the reverse of this takes place in freezing. The crystallization of water is attended with an elevation of temperature. The heat which vapor carries with it in its aërial journeys is liberated when those vapors are transformed into flakes of snow. The expression we often hear when a storm in winter is imminent, that "the cold is too great for snowing," is true enough. The air is made warmer when snow-flakes begin to form, and the temperature is higher than it would otherwise be while snowing continues. In this way the formation of ice and snow modifies and softens the temperature of arctic winters; and the blossoms which open with the spring-time are not more significant of milder airs than are those which are born of frost and vapor, and expand their petals to the winter's tempest. Snow-flakes are stellate in form; the molecules of vapor in crystallizing

aggregate in six-rayed figures, but in endless diversity of patterns. Captain Scoresby figured 96 of these, beautiful illustrations of which are shown in the plate. And Nature is profuse of these "frozen flowers." On mountains, and amid solitudes of the North unseen by man, she scatters them as she does those which waste their perfume in the desert. The delicate lace-like figures which follow the touch of frost on the window-pane are of the stellate type, but, being modified by disturbing influences, develop into gorgeous patterns.

Ice, when decayed, is weakened and becomes soft throughout, scarcely more compacted than snow. By rains and mild weather of spring, ice on our Northern lakes is thus impaired. In this condition it is said to be "honey-combed;" and, while yet many inches in thickness, and apparently solid, is unsafe to travel over. The foot of a horse will pass through it, displacing merely the portions beneath, and without fracture of the surrounding parts. This arises from the prismatic structure already noticed; and it is along the lines of adhesion of the prisms that the ice first yields to the invasion of heat. When thus weakened, it will sometimes disappear from the surface of a lake by a few hours of heavy storm, or, if any portion remain, it will be in the form of crystals, thoroughly permeated by water. So rapidly has it vanished in many instances from lakes, that its sinking was insisted on, but it is now known that it disintegrates and disappears by internal liquefaction.

A most interesting and important property of ice remains to be noticed. We refer to that by which it may be moulded into almost any form by pressure. Cubes of solid ice have been pressed into balls, cups, rings, and other shapes, showing its extraordinary plasticity. At a temperature of 32°, ice is by no means a rigid substance, but readily yields to pressure. Placed in the cavity of a mould (Fig. 6), it is broken into innumerable fragments as pressure is applied. It has

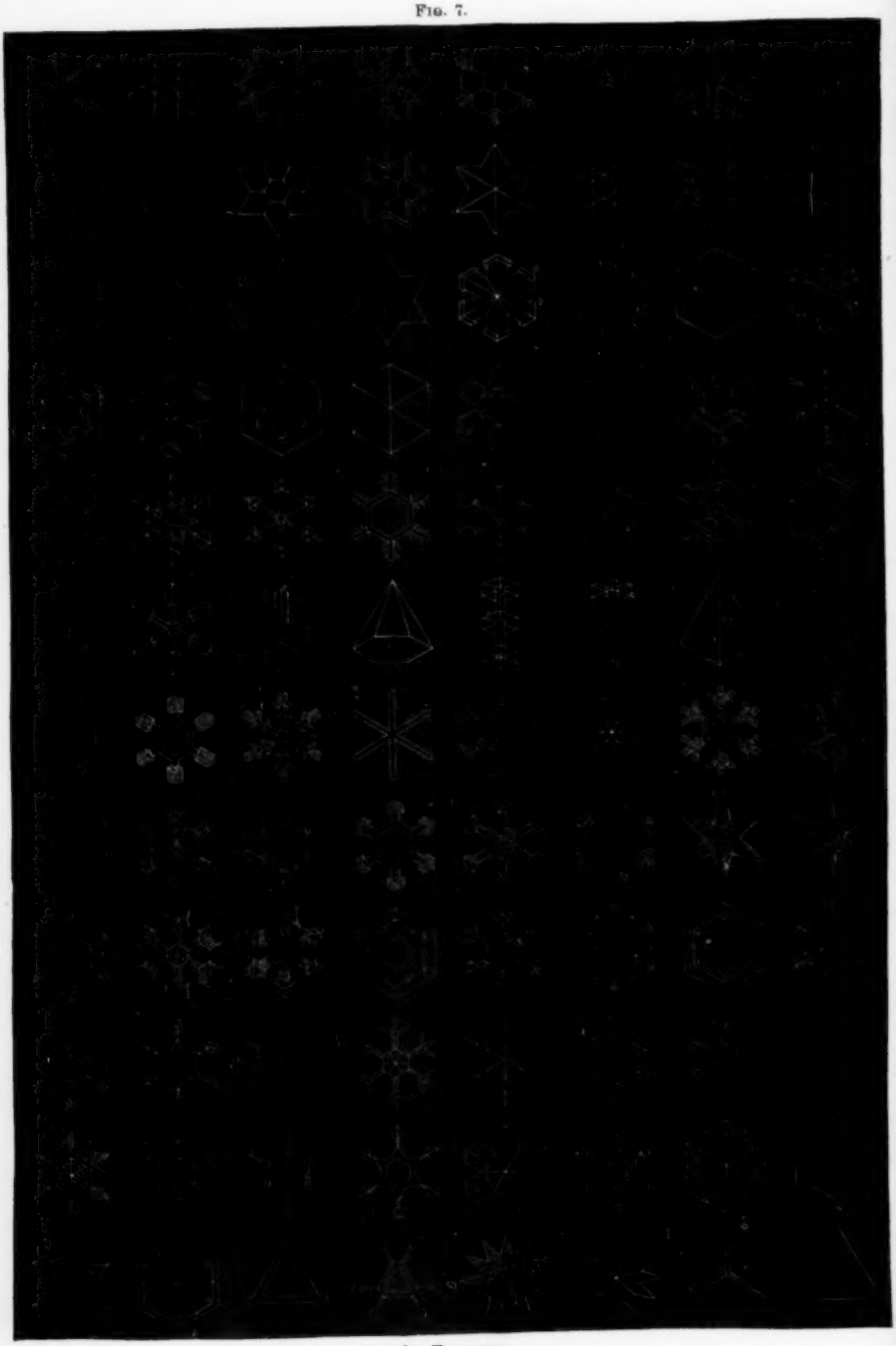
FIG. 6.



MOULD AND BALL OF ICE FORMED BY COMPRESSION.

been shown, however, that, unless the crushing be sudden, the ice is not reduced to a granular or powdery mass, but maintains its cohesion while it undergoes change of form. During the process a portion of the ice becomes liquefied, and the water escapes, carrying with it the heat liberated in the liquefaction, but the portions remaining are moist, and at each point of contact directly adhere together by freezing of the moisture. This refreezing takes place throughout the mass,

FIG. 7.



ICE-FLOWERS.

molecule to molecule, particle to particle, mass to mass, and a ball or other figure of solid ice is the result. If there be no moisture, there can be no refreezing until moisture is produced or applied. Thus pieces of ice below the freezing temperature will not adhere because the surfaces are dry. The same is true of dry, granular snow in very cold weather—only by long-continued moulding and pressure in the hands can it be compacted. But in this case some liquefaction has been produced, and then the surfaces in contact freeze together. Snow, in the upper Alps, often covers gorges in the glaciers, and if moist can be trodden into bridges sufficiently compact to pass safely over.

This property of ice and snow Prof. Tyndall calls regelation. It was discovered by Faraday in 1850, who found that moist surfaces of ice adhered if brought together. This occurs under water as well as in the air; at summer heat, and beneath water so hot as to be painful to the hands. The phenomenon may be explained in this way: If we hold in our hands two cubes of ice, their outer surfaces are exposed to the atmosphere, and, if it be warm enough, some liquefaction at the surfaces takes place, and they become moist. Now, if the cubes be brought together, two of the outer surfaces become inner ones, and the moisture, chilled to the temperature of the ice, freezes, and the two cubes become one mass. It is because the molecules of ice may be continually crowded into new positions that the mass may be changed in form without its continuity being broken. A slab of ice placed in a suitable position will bend by its own weight. In this case the molecules throughout undergo gradually a change of position; but, if the stress be too rapidly applied, fracture occurs.

All the properties and phenomena of ice which we have considered, and in a marked degree that of regelation, are shown in the growth and movement of glaciers. In these we see the development of ice on its grandest scale. Equally in structure and form in molecular and molar motion they are an expression of energies that are irresistible and sublime. "To produce from aqueous vapor," observes Prof. Tyndall, "the little mass of snow which a child can carry, demands an exertion of energy competent to gather up the blocks of the largest stone avalanche I have ever seen, and pitch them to twice the height from which they fell." Who, then, shall estimate the potential energy of the great ice-rivers of the Alps, or of the glaciers of the Arctic Zone?

The motion of the Mer de Glace, and of other glaciers, is so slow as to be ascertained only by persistent observation, or by careful measurement. In 1827 a hut was erected by Huji on the glacier of the Unteraar for purposes of observation, but the hut was found to move down the valley. In fourteen years it was nearly a mile below its first position. In 1820 three mountain-guides were plunged by an avalanche into a gorge of a glacier on the side of Mont Blanc. After a burial of forty years in the ice, they were found several miles below the spot

where they were lost. The velocity of a glacier depends chiefly upon the angle of slope over which it moves. The hut of Huji moved 336 feet in a year. But the motion in different portions of a glacier is very unequal, slow at the margins and at the bottom where friction retards progress, but may attain a velocity of three feet or more in a day at its line of most rapid flow. It has been estimated that the ice-sheet which covered New England at its greatest development in the glacial age may not have advanced more than a foot in a week, a mile in a century.

A question has arisen, Do glaciers slide upon their beds? It seems to be conceded that sliding takes place to a limited extent. It may occur where the uniform flow of the glacier is interrupted, and separation of its parts produces crevasses, as along its margins, and over an uneven bed. We are chiefly concerned, however, with the motion which has its origin in the physical properties of ice.

The flowing of a glacier may be quite independent of its sliding motion, if such it has. It flows because of its plasticity, its molecules undergoing incessant change of position as they do in ice under pressure, and regelation goes on throughout the mass. By these means its cohesion and continuity are maintained.

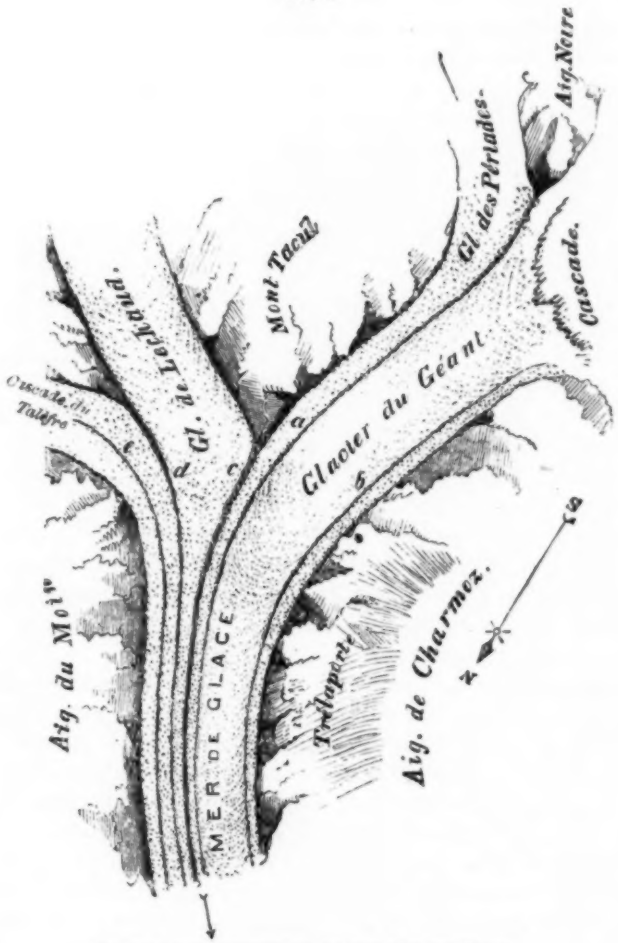
It is often stated that the temperature of the interior of a glacier must be much below the freezing-point. This is probably an error, the temperature throughout differing but little from 32°. The pressure, indeed, may be enormous, and portions of the ice be liquefied by it, but the water which is "ice-cold" escapes through innumerable fissures, and the freezing-point is not lowered by the pressure, as it would be if the water of liquefaction did not escape. The constant flowing of a glacier necessitates unceasing supply, and its source is found accordingly in that zone of elevation where snows accumulate. The snow-fall of which the glacier is born implies vapor clouds and condensation, and equally evaporation, the proximity of a warm climate and expanse of ocean. Hence it is inferred that cold and warm climates were contiguous during the age of glaciers, as they are at this period of their decline. Glaciers relieve the land of accumulating snows as streams do of excess of waters. But for these, mountains reaching above the line of perpetual frost would become buried, and the "ocean piled upon the land." But such a process has its limitations in the economy of Nature.

The snow which falls in great volume upon mountains is a dry powdery mass, and cannot be consolidated until some liquefaction has taken place. This quickly occurs. Through the clear air of great altitudes the sun's rays fall with intense power upon objects, even while the temperature is at freezing in the shade. Portions of the surface snows are thus melted, the under portions are moistened by the percolating waters, and regelation begins. The phenomenon of the snow-ball is here reproduced on a gigantic scale, differing in this:

in the one case liquefaction is produced by pressure, in the other by solar heat. Gradually the under-layers become incipient glacier-ice.

Movement of the mass originates in its gravity, and the direction must be down the slope on which it lies. Many streams in this way blend into immense rivers of ice, often several hundred feet in depth. The snow when first consolidated is filled with air-bubbles, and is white and opaque. Its whiteness disappears by expulsion of the air-

FIG. 8.



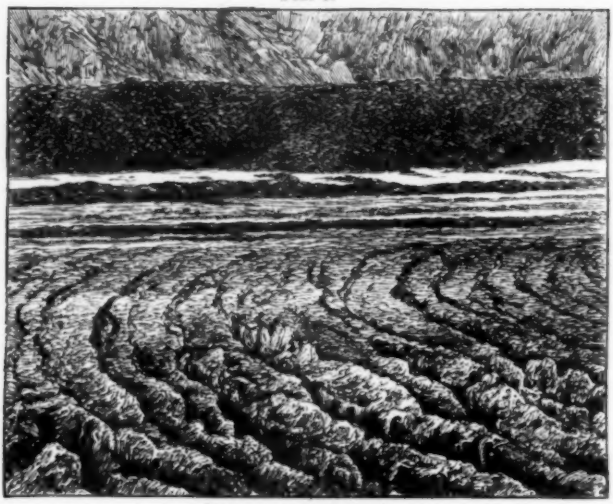
SHOWING THE CONFLUENTS OF THE MER DE GLACE.

bubbles from pressure as the glacier moves down the valley. At its termination the ice is transparent, and its exquisite tints of blue indicate the extreme minuteness of the reflecting surfaces which linger in it.

The physical properties of ice by which it flows need not be re-

stated further than to mention that the opinion of Prof. Forbes, that it flows as a "viscous substance," is not accepted. Wax, we may say, is both plastic and viscous, and yields equally to pressure and to tension. Ice yields to pressure, but not to tension. It cannot be stretched. Glaciers maintain their cohesion under pressure as plastic bodies, but, wanting viscosity, they break into profound chasms where the tension is great. In ice, therefore, one property is wanting to render it a viscous substance. In Fig. 9 is beautifully shown the opening of crevasses on the margin of a glacier, where the flow is retarded by friction. A like phenomenon occurs when a glacier falls in a cascade over a precipice. Then chasms appear of startling

FIG. 9.



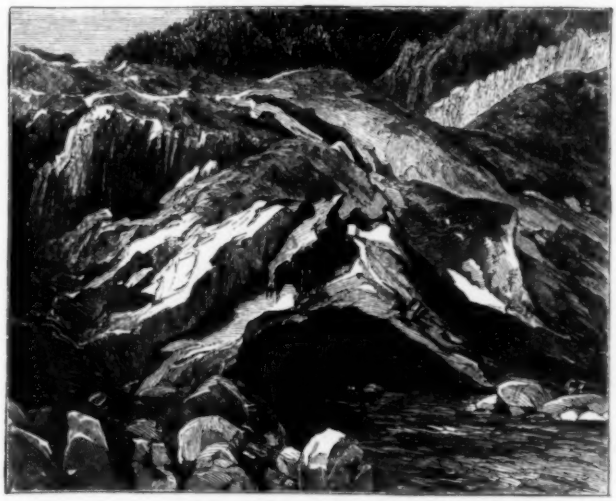
MARGINAL CREVASSES.

depths, and gigantic blocks of ice are thrown into the wi dest confusion. From the chaos come sounds which indicate what is going on below. The nether air is filled with echoes from the murmur or roar of water, the falling of bowlders, and crashing of ice. At the foot of the fall the broken fragments of ice are crowded together, become solid by regelation, and the mass moves on.

The terminus of a glacier may be many thousand feet below the limit of perpetual snow before its disintegration is complete. But the wonderful fabric falls at last, as heat destroys its molecular framework, and is lost in the turbid flood which forever pours from beneath its portals. But the sediment of the incipient rivers thus formed was no part of the crystalline structure, for crystallization casts out impurities, and gathers neither soil nor stain in its beautiful textures. The sediment arises from abrasion of solid matters held in the under-surface of the glacier upon the rocks of its bed. In Fig. 10

is shown the source of the Arveiron and the sublime view of the foot of the glacier whence it issues. Of this M. Rendu says, "It is a vast portico more than a hundred feet high, let into an immense *façade*, and surmounted by lofty pyramids of ice. Nothing is more astonishing than this work of the elements, of which Nature alone has conceived the plan, and achieved the construction."

Fig. 10.



Source of the Arveiron.

Ice presents, under pressure, many phenomena of great interest other than those mentioned, and to which we can only refer. The prismatic or crystalline form, so beautifully developed in lake-ice, is more or less destroyed in glaciers by the unceasing fracture and regelation which takes place from pressure, and the mass assumes a granular structure. The same phenomenon occurs with ice in a mould. In glaciers are veins which reflect a deeper tint of blue, indicating where from local causes greater or more persistent pressure has cleared it of bubbles of air. Glacier, and probably other ice, under similar conditions of pressure, becomes laminated, or develops planes of cleavage, resembling those of slate-rock in the quarry; and this structure is shown in the decay of the ice, as its prismatic structure is shown in the decay of that on lakes and rivers.

By the physical properties we have noticed, ice becomes a dynamic agent of tremendous power. The play of forces and plasticity of structure which make it a toy in the laboratory, have changed the aspects of Nature, and modified the surface, as they have the distribution of life, upon a large portion of the globe. Rocks are broken by its expansive energy, but they are also crushed by its weight, and ground to dust in its irresistible motion. A sheet of ice a mile in

thickness rests upon the bed, over which it moves with a pressure of more than 260,000 pounds for each square foot of surface, and many such as this covered the old glacier-regions through an unmeasured period of time. In their movement lakes were excavated, water-courses changed, and landscapes cast into innumerable forms of beauty. We utilize the results. Our forests and our harvests grow upon soil ground in the glacial mill, and we build our cities on mounds of glacial rubbish. Nor can we fail to realize that here, as elsewhere in the phenomena of Nature, there is a ministration to our conscious life, as there is an appeal to our sense of beauty, and that, whatever form it may assume, whether of the feathery spangle which rocks upon the waves of air, or the profound glacier that buries a continent, ice is Winter's benefaction.

THE DEVELOPMENT OF PSYCHOLOGY.

II.

J. S. Mill—Bain—Spencer.

GREAT as were the services of Mr. John Stuart Mill to Philosophy in general, and Psychology in particular, we cannot ascribe to him any notable advance in psychological doctrine, or in the conception or application of psychological method. In doctrine, his chief contributions were the restatement, in a form adapted to the changed conditions of the controversies, of Berkeley's theory of material, and Hume's theory of mental, existence. But neither the psychological theory of mind nor the psychological theory of matter contains any new principle, or exhibits any new way of applying old principles. In constructive method, he could get no further than Brown's half-century-old "chemistry of the mind," and though he earnestly recommended the St. Andrew's students to make the acquaintance of Physiology, as supplying to Psychology the principles of predisposition, habit, and development,[1] he never made the smallest use of these principles himself, and had not a single word to say in favor of Mr. Spencer's use of them.[2] That he still traded on the old conceptions is evident from his metaphors: the "thread of consciousness" is a decided advance on Locke's "gang of ideas," but he shies at Prof. Masson's "organic union" of states, and prefers to connect them by an "inexplicable tie."[3] Mill, in fact, was above all things a logician, and whatever he accomplished in the sciences was in virtue of his clear perception of the extent of a principle, the limitations to which it was subject, and the conditions under which it could be most fruitfully ap-

[1] "Inaugural Address," pp. 61, 62. [2] "Dissertations," iii., 99, note.
[3] "Examination" (third edition), pp. 256, 257.

plied. His services to psychological method were of this order, and therefore belong rather to the logic of science than to the history of Psychology. But, as his luminous exposition of the logical *status* of the "laws of mind"[1] had an unquestionable influence on the most systematic application of these laws yet made, in the comprehensive work of Prof. Bain, it will be proper to inquire whether this advance too had its antecedents in the physical sciences.

Mill's logic of psychology is characteristic. Like all his doctrines, it has a positive and an hypothetical part—the hypothetical admitting almost all that his opponents of every school would assert, and the positive so stated as if those admissions had not been made. The positive aspect of it may be embodied in three propositions. Psychology is a *science*, because the facts of mind present certain uniformities of succession, which we call laws. It is an *independent* science, because its laws are ultimate, and cannot be deduced from the physiological laws of our nervous organization. Finally, this science has certain *limits*, which are stated, however, with a vacillation and obscurity very far from usual with so clear and resolute a thinker, but which appear to be: that sensations of one sense cannot be resolved into those of another; that "the other constituents of the mind, its beliefs, its abstruser conceptions, its sentiments, emotions, and volitions," have probably not been generated from simple ideas of sensation; and that, even if this can be proved, "we should not be the more enabled to resolve the laws of the more complex feelings into those of the simpler ones." In the hypothetical part (which has been much more strongly expressed in the later editions of the "Logic," though without any corresponding alteration of the positive part), Mill is quite prepared to admit that "the laws of mind may be derivative laws resulting from laws of animal life, and that their truth, therefore, may ultimately depend on physical conditions." But the probability of this genesis being shown, he apparently regards as so remote that it is not worth while to take the antecedent physical conditions into account except as disturbing agencies.[2] He refuses to see that if the evolution of the higher forms of life from the lower can be made out, we do not say as an induction, but even as a good working hypothesis, the foundations of Psychology will be subverted, and it will be changed from what we may call a statical into a dynamical science.

Mill belonged, less by age than by precocious mental development, to a generation which found in him its perfect scientific, and in Mr. Carlyle its most consummate literary, expression. In literature, it turned with reverted eyes to an ever-receding golden age, and wrote histories; in science, the impulse was rather to widen, clear, and connect the old paths, than to strike out in new directions—to get round obstacles, than to tunnel them. "Reaction" is so ready a spell to

[1] "Logic" (sixth edition), ii., pp. 431, 442.

[2] "Logic," ii., 433.

conjure meaning out of facts by pretending to put an explanation upon them, that we will not ascribe the critical mood of the last generation to mere revulsion from the profuse hypotheses of the period when Chemistry promised to reveal the secret constitution of Nature; but, clearly, after a time of discovery and accumulation of facts, there comes the necessity for arrangement, classification, method, and the logician takes the place of the discoverer. To this work the generation of 1820–1850 set itself in no scholastic spirit, and one of its first achievements in the new field was Herschel's picturesque and elevated "Discourse."[1] Ardent and imaginative as is that fine essay, it is nevertheless essentially logical. Four of his nine "rules of philosophizing" were converted by Mill into the experimental methods, and thus made a part of the logic of proof; his conception of a law is predominantly that of a generalization which seems to imply no inductive leap; and he appears to look for the openings to future discovery in the purely analytic direction of finding some more general laws of which the laws already discovered are cases. So faithfully did the work embody the tendencies of the period that its phraseology at once became classic, and its ideas of cause and law the commonplaces of science. They certainly formed a large portion of the mental pabulum of Mill, and are reflected, though with infinite widening and clarification, in the "System of Logic." We have already said that his four "methods" were but four of Herschel's "rules;" Herschel's "presumed permanence of the great laws of Nature" appears in Mill as the statement that "the uniformity of the course of Nature is the ultimate major premise in all cases of induction," and the relations of induction and deduction, the value and test of hypotheses, the nature of empirical laws, and the analysis of cause—are all striking *aperçus* which Mill pursued to their limits on every side, and thus was able to give to the exposition of them systematic completeness. All these conceptions, as being important parts of the logic of science, belong equally to the logic of psychology, and, if their statement in reference to mental science is due to Mill, the statement of them in reference to science generally is due to Herschel. But we are here more concerned to point out that the scientific conditions laid down by Mill as defining the logical *status* of psychology belong to the type of physical investigations of which Herschel was an early representative. The definition of science as having for its subject "uniformities," the description of the independence of a science as arising out of the irreducibility of its laws to other laws, and the exposition of the limits of scientific inquiry—all find their prototypes in the "Discourse." Here again, therefore, the advance in Psychology, though only logical, had its initiative in the physical sciences.

The rate of change quickens as the type of social structure rises, and the progress made by Psychology within the present generation

[1] "Preliminary Discourse on the Study of Natural Philosophy," 1830.

is not only far greater than has been before made in any period of equal length, but greater than has been made since the foundation of the science. The large acquisitions of new facts, the faithful description of phenomena, the reduction of them to law, and the investigation of the physical "sides" of mental products, which we owe to Prof. Bain, and the application to mind of the revolutionary principle of development, and the inclusion of it within the larger philosophy of evolution, which we owe to Mr. Herbert Spencer, have changed not only the aspect but the constitution of Psychology. Like all the previous advances we have recorded, the developments due to both of these distinguished psychologists have had their dynamic in the subsidiary sciences.

Mr. Bain describes his work as being "the first attempt to construct a Natural History of the Feelings, upon the basis of a uniform descriptive method," and the characterization is just. All preceding surveys of the mind had been undertaken to establish a doctrine, as by Hobbes; to refute a theory, as by Locke; to prove an hypothesis, as by Hartley; or to furnish analytical justification of a foregone conclusion, as by the elder Mill. Mechanics, Natural Philosophy, and Chemistry, having exhausted their constructive impulses on Psychology, it was reserved for Mr. Bain to adopt a method which makes no presuppositions, rests on no hypothesis, and conducts to no necessary conclusions—the method employed in the organic sciences in their undeveloped state. The natural history "method" is very old. The first full-blown specimen of a naturalist, whose reputation has reached posterity, appears to have been Solomon, and of him it is said that "he spake of trees, from the cedar-tree that *is* in Lebanon even unto the hyssop that springeth out of the wall: he spake also of beasts, and of fowl, and of creeping things, and of fishes."[1] Linnæus was even more comprehensive, and added minerals to plants and animals; but with him the differentiation of science and accompanying specialization of method begin. The first great classifier himself constituted Botany a separate science; Haüy followed with Mineralogy; the discovery of Oken (or Goethe) and the theories of St. Hilaire founded Comparative Anatomy; Comparative Physiology issued out of its sister science; and morphological and functional divisions of all these sciences were successively established. With such advances in classification, the natural history method becomes immensely more complex, but its character is fundamentally the same—that of description. We cannot better exemplify this than by quoting the words of Dr. Carpenter. Contrasting him with the "enterprising discoverer," the horticulturist, and the breeder, he says that—

"The philosophic naturalist. . . . aims to reduce the number of species, by investigating the degree of variation which each is liable to undergo, the forms it assumes at different periods of its existence, the permanent characters by

[1] "First Book of the Kings," iv. 33.

which it may be distinguished during its whole life, the habits which are natural to it, the degree in which these may be changed by the influence of circumstances; and, in fine, he endeavors to become acquainted with the *whole* Natural History of a reputed species, before separating it from another to which it may be closely allied."[1]

The "philosophic naturalist" plainly requires just so much philosophy as is implied in keeping his eyes open, and, indeed, so long as species were believed to be separately created, and organic characters could be only correlatively and not genetically explained, there was nothing else for him to do. Natural History before Darwin was like Natural Philosophy before Newton; its inductions were incomplete, and the deductive procedure which could alone raise its constituent groups into sciences was impossible. It was at this stage in the development of Natural History that Mr. Bain took up its method, and set about applying it to the "Feelings." Its power in the hands of a keen and dispassionate observer is indisputable, and the two instructive volumes which contain Mr. Bain's systematic exposition are at once a treasure-house of observations of priceless value, and such a compendious generalization of mental facts of all orders into laws as doubtless marks the climax of the method. But it is fundamentally unscientific. If it be true that the higher forms of life and mind have been evolved out of the lower, then the most resolute introspection, and the most cutting analysis, with the help of stray observations of children, and some patient experimenting on animals, will go no appreciable distance in discovering mental constituents which may have had their origin in an indefinitely remote past. That this is not only a necessary result of the "natural history method," but that it has in point of fact resulted in Mr. Bain's treatise, it may be well to make clear. To keep the analogy in view, we again quote from Dr. Carpenter. "The naturalist," he says—

"endeavors to simplify the pursuit of his science, by the adoption of easily-recognized external characters, as the basis of his classification of the multitudinous forms which he brings together; but such can only be safely employed when indicative of peculiarities in internal structure, which are found to be little subject to variation, and which are not liable to be affected by the influence of physical causes."[2]

Now, such an endeavor to simplify, by the adoption of easily-recognized external characters as the basis of his classification, is a feature prominent in the fore-front of Mr. Bain's work. The mode of diffusion of an emotion, the institutions it generates, and its peculiarities as a state of consciousness—all of them the most manifest characters of the emotions—are avowedly adopted as bases of classification.[3] That easily-recognized external characters are not always "indicative of

[1] "Comparative Physiology" (fourth edition), p. 632.

[2] *Op. cit.*, p. 633.

[3] "Emotions and Will," *first* edition.

peculiarities in internal structure," has been shown by Mr. Spencer, and is indeed a corollary from the theory of development.[1] Mr. Bain's method is therefore misleading from its contracted range, but we must here record, as part of our history, its very great advance on the still more incomplete methods of the older psychologists.

Mr. Bain's other contributions to Psychology are connected with the recent development of one of the sciences whose general method he appropriated. The physiology of the nervous system was of late foundation. Vesalius, Fallopius, Vieussens, Boerhaave, and Willis, had indeed assigned the special functions of certain organs (as those of the senses) to their appropriate nerves, but even in the middle of the eighteenth century the great Haller could deny the existence of any nerve which did not possess the double function of sensation and motion. Whytt and Prochaska, in 1768 and 1800, made observations on reflex and spontaneous movements, and decisively raised the question of the mode of action of the nervous system. In the first quarter of this century Sir Charles Bell established the existence of two great systems of nerves, with different functions, and thus revealed a definite mental mechanism. A few years later Dr. Marshall Hall (or some one else) discovered the independent action of the spinal cord, and helped further to determine the organic conditions of mental activity. His contemporary, Müller, went so far as to assert that the spinal cord was the centre or source of *all* motor power. At this point Mr. Bain came into the field. Appropriating the discovery of Hall, he was the first among psychologists to attempt systematically to elucidate the spontaneous movements, as no less a part of the phenomena of mind than those of consciousness. Combining Bell's discovery with a hint of Müller, he introduced the first organic modification into the association psychology by his theory of the brain as a fountain of force and not merely the passive instrument of impressions. This theory has led him, not only to take into account the secondary mental states generated by the bodily organs, but to trace genetically the origin and growth of voluntary power, and thus to constitute a separate department of Psychology by the analysis of volition, which had previously been the victim of introspection. It has also led him to devote a section to "constructive association," which could have no place so long as there was recognized in the mind no power of original construction. The tendency to materialize the mental agencies—the assumptions that nerve-force is of the nature of a current, that it moves in diffused waves, that associations are generated by shocks—are consequences partly of the introduction of the same new element. They are consequences also of that assumed correlation of the mental and nervous with the physical forces which Mr. Bain has, in his later editions, done much to prove and illustrate.

"If Mr. Herbert Spencer had no other titles to fame, he would

[1] "Essays" (second series), p. 125.

still be the greatest of psychologists. The vast constructions of his 'First Principles' will ever be a monument of his extraordinary powers of generalization. His designed organization of the Social Science opens up the prospect of intellectual acquisitions in the future to which the past may furnish few parallels. But the 'Principles of Psychology' will still remain, in its symmetrical completeness and perfect adequacy to the subject, at once the most remarkable of his achievements and the most scientific treatise on the Mind which has yet seen the light. Its publication in 1855 did not make a sensation. The persistent efforts of Mill had not yet succeeded in stemming the muddy tide of the prevailing scholasticism. The bastard Kantism of Hamilton did duty for metaphysics, and the Common-Sense philosophy of Reid, with the common-sense left out, usurped the place of Experimental Psychology. Experimental Psychology was, as usual, busy with analysis, and had no eye for the merit of an imposing synthetical effort. Mr. Spencer's work had accordingly a chill reception. Greeted by the aristocratic metaphysicians with a few words of courtly compliment, but treated practically with supercilious disregard, it was received by psychologists of the Association school with hardly more favor than the snarling approval with which a Constitutional Whig views the entry into the Cabinet of a Birmingham Radical. Mr. Spencer was ahead of his generation, and paid the penalty of his prescience in twenty years of neglect. But now the wheel is coming round. The bovine British public, constitutionally disposed indeed to apathy, but drugged into a leaden slumber by its medicine-men, is at last awakening to the fact that the peer of Bacon and Newton is here. Writers of all schools are hastening to define their position with reference to the Synthetic Philosophy." A younger generation has grown up, with minds unhardened by the limitations of obsolete Sensationalism, and inclined rather to a somewhat undisciplined acquiescence in what the Germans call "world-shattering," that are also world-constructing, theories. But "whatever part of his philosophy may be transitory, Mr. Spencer's present influence is indisputable; and, since the lamented death of Mill, no one can now contest his claims to the philosophic supremacy in these islands. That supremacy rests mainly on his Psychology." Cosmological speculation has been so long out of date that we are hardly yet able to incorporate his "first principles" as a vital and vitalizing part of our mental acquisitions. Sociological inquiries are just coming into fashion under the dusky auspices of the "savage races;" but the Social Science, though undoubtedly destined to play a great part in the immediate future, still wants an audience, except for sanitary discussions in autumn among peripatetic philanthropists in provincial towns. But Psychology, at least, the kind of thing found in Reid with an infusion of Hamilton, has long formed part of the higher education in Scotland; and at one of the English universities the hash of cosmology,

metaphysics, logic, and ethics, named Aristotelianism, yields under pressure some small psychology. Besides being, therefore, in whatever rudimentary forms, a pet academical study, much encouraged by philosophically-minded Heads, the science itself is vastly further advanced than any of the mental sciences, its province is tolerably well defined, in the statement, at least, of its main problems the most opposite schools agree, and both likewise agree in the tests to be applied to their solutions. A pretender to psychological discoveries has accordingly a decided advantage over his brother discoverer in the more embryonic mental sciences in so far that, if he is not out of sight ahead of his generation, he can secure a competently-instructed audience, eager and, on the whole, capable to decide on his pretensions. The extreme fascination of Mr. Spencer's theories, and doubtless their fundamental truth, have obtained for him a large *clientèle;* and the position of the philosophy of mind as the foundation of all other philosophies, social, ethical, æsthetic, and political, has created channels through which his characteristic ideas have percolated in all directions. Such a supremacy as this could only have been gained, if our history of the parallel development of the physical and mental sciences be exact, by a substantial identity of the method and unity of the principles of the synthetic psychology with those of the last-developed organic and inorganic sciences. We shall see that this is the case.

Mr. Spencer's numerous psychological advances may be grouped in two divisions; the application to mind of the theory of development, and the connection of psychological evolution with evolution in general. The last edition of his work also incorporates Mr. Darwin's law of natural selection in the explanation of the emotions, but this may be regarded as simply an extension of the development theory. In the working out of both principles, Mr. Spencer has followed the lead of the physical sciences.

Before it could be discovered that species were evolved from one another, it had to be discovered that there were among them fundamental kinships. The foundation of the comparative sciences was the beginning of the movement, and we suppose that Goethe's "Sketch of a Universal Introduction into Comparative Anatomy" may be regarded as striking the first note. Thirty years' further research reduced the skull of all vertebrate animals to a uniform structure, and determined the laws of its variation. In 1820 Audouin partially succeeded in filling up the chasm between insects and other animals. In 1830 Laurencet and Meyraux assimilated the structure of mollusks to that of vertebrates. Out of these discoveries an internecine war arose between the schools of Cuvier and Geoffroy St.-Hilaire, the former contending that the structure and functions of animals should be studied in the light of final causes, the latter setting up their analogies as the only safe guide. And out of the struggle came the new philosophy. "*The principle of connection*," says Whewell, "*the elec-*

tive affinities of organic elements, the equilibrization of organs—such are the designations of the leading doctrines which are unfolded in the preliminary discourse of his" (St.-Hilaire's) "'Anatomical Philoscphy.' Elective affinities of organic elements are the forces by which the vital structures and varied forms of living things are produced; and the principles of connection and equilibrium of the forces of the various parts of the organization prescribe limits and conditions to the variety and development of such forms."[1] Now for the first time we hear such phrases as "unity of plan," and (more significant still) "unity of composition." Then came Von Baer's law of progression of structural development from the general to the special, afterward extended to functional development, and giving rise to the conception of the specialization of functions. Out of this, too, arose the term "evolution," and, though confined to organic development, implied an advance in generalization. The mere mention of such further advances as are implied in the establishment of the functional identity between the contractile tissues of plants and those of the higher animals; in the use of the phrase "psychical powers" to designate the sensorial and mental endowments of animals; in the proof of the absence of specialized sensibility among the lower tribes of animals, and of the hereditary transmission of certain characters acquired under the influence of *external* circumstances; in the parallel traced between the progressive complication of the psychical manifestations during the early life of a human being, and the gradual increase in mental endowment to be observed in ascending the animal scale[2]—may serve to indicate the conceptions forming the matrix in which a philosophically constructed Psychology was to be moulded. How great a revolution had taken place in biology, and how far we have now got from the natural history method, may appear from Prof. Huxley's definition of "zoological physiology," which, though made some years after the first publication of the "Principles of Psychology," at least points out the direction in which thought had been moving. He says:

"It regards animal bodies as machines impelled by certain forces, and performing an amount of work, which can be expressed in terms of the ordinary forces of Nature. The final object of physiology is to deduce the facts of morphology, on the one hand, and those of distribution on the other, from the laws of the molecular forces of matter."[3]

With a prescient insight into the future of science which has probably few parallels, Mr. Spencer founded his Psychology on the hypothesis of development. To all but a few deep-thinking observers there can have seemed few signs in 1855 that that hotly-disputed theory was ever likely to be in the ascendant. The exposition of none of the

[1] "History of Inductive Sciences," iii., 504.

[2] *See* Carpenter, "Comparative Physiology," *passim*.

[3] "Lay Sermons," pp. 106, 107.

organic sciences that we know of had yet been based on it, and its application to mind was undreamed of. But with a confidence in the intuitions of reason which is one of the clearest attributes of speculative genius, and which may have its analogue in the statesman in the nerve to take the vessel of the state over a bar, Mr. Spencer assumed the provisional truth of the theory, and it might be difficult to exaggerate the extent to which his exhibition of it in Psychology has contributed to its establishment.

It was first requisite to find a generalization on which to base a synthetic Psychology. The assumption being made that mind and bodily life are but subdivisions of life in general, it was required to seek out some characteristic common to both—some characteristic of vital actions in general, and distinguishing them from non-vital actions. Applying a method which Prof. Stanley Jevons has omitted to note in his "Character of the Experimentalist," Mr. Spencer arrives at a definition of life of which the essential point is that it implies a correspondence between life and its circumstances. Here is the first notable advance—the inclusion of the environing world in the definition of the science of mind; and in this is contained the germ of Mr. Spencer's later differentiation of Psychology and circumscription of its province.[1] If correspondence with the environment is the *differentia* of life, it is almost an identical proposition to assert that the *degree* of life will vary with the completeness of the correspondence and the complexity of the environment. An ascending synthesis accordingly finds the correspondence at first direct and homogeneous, then direct but heterogeneous, as extending in space and in time, and as increasing in specialty, in generality, and in complexity. Along with the all-sided development thus going on in the correspondences, there goes on a development in the degree in which the organs and functions of the individual are so correlated and united as to respond promptly and effectually to the answering changes in the environment. Contemplating now the correspondences in their totality, it is found that the generalization on which it was proposed to base a synthetic Psychology is established, that manifestations of intelligence are found to consist in the establishment of correspondences between relations in the organism and relations in the environment, and the preliminary assumption that life and mind are fundamentally identical is proved.

Nevertheless, though these two kinds of life are primordially the same, they are in their general aspects widely unlike, and we must inquire whence the differences arise. Instinct, Memory, Reason, Feeling, and Will, have specific differences; a science of Psychology which is based on the theory of development must determine whence these

[1] "Psychology," second edition (1870), volume i., section 53. Swedenborg's "Law of Correspondences" is not without analogy to Mr. Spencer's original generalization.

arise, and, if mind is merely a higher manifestation of life, they must be interpretable as life was interpreted.

Intelligence in general is differenced from life in general by the fact that the order of changes of which it consists is successive. The science of intelligence having thus for its subject-matter a continued series of changes, it is the business of Psychology to determine the law of their succession. Bringing up the "law of correspondences" left in the rear, it is found that one mental state tends to follow another with a strength proportionate to the intimate union between the external things they represent. Here is a "law of association" of Hegelian depth, cutting down to the adamantine pillars of the universe, and compared with which the so-called laws of association are mere empiricism. The law is also of Hegelian content—rivaling that cocoon *das Werden*, and out of it shall be woven all the phenomena of unfolding intelligence. Reflex action we have already seen Mr. Bain incorporate in Psychology; Mr. Spencer shows how it necessarily arises out of developing life. Instinct, too, Mr. Bain prefixes to his analysis of ideas; Mr. Spencer evolves it out of reflex action. With the increasing complexity of experience Memory arises, and Mill's "insoluble problem" is solved. The chapter on Reason is, perhaps, the finest synthetic exposition in the literature of Psychology. Reason, like Memory, is shown to be developed by an insensible transition out of instinct; and Locke is reconciled with Kant by the intervention of that theory of the secular transmission of mental acquisitions which has become so familiar that it is now difficult to appreciate its daring originality. Feeling, like Reason, arises out of instinct; and emotions of the greatest complexity, power, and abstractness, are formed out of the simple aggregation of large groups of emotional states into still larger groups through endless past ages. Thus out of the feeble beginnings of life have been woven all the manifestations of mind, up to the highest abstractions of a Hegel and the infinitely complex and voluminous emotions of a Beethoven. Well may a French writer say: "Si on la rapproche par la pensée des tentatives de Locke et de Condillac sur ce sujet, la genèse sensualiste paraîtra d'une simplicité enfantine."[1]

Hitherto the psychologist, proceeding objectively, has made no use of consciousness; and it is now necessary, in order to justify the findings of the synthetic method, to examine consciousness in the only possible way—by analysis. Setting out with the highest conceivable display of mind, compound quantitative reasoning, he tracks all the mental phenomena down to that which is *only* a change in consciousness, the establishment of the relation of sequence, and proves that the genesis of intelligence has advanced in the same way as was shown in the synthesis—by the establishment and consolidation of relations of increasing complexity. Thus throughout all the phenomena of

[1] Ribot, "La Psychologie Anglaise," p. 215.

mind there exists a unity of composition; and the doctrines of innate ideas, intuitions by gift of God, supernatural revelations, mysticism of all kinds, have the ground cut from under them.

The very great extension of plan which Mr. Spencer's work received between 1855 and 1870–'72 was due solely to the creation of his own philosophy of evolution. That in its turn had its initiative in the theory of the correlation of forces advanced by Grove in 1842. As the new philosophy conceived all existence to result from evolution through differentiation and integration, it was incumbent on Mr. Spencer to show that mental phenomena, or at least the physical correlatives of them, can be interpreted in terms of the redistribution of matter and motion, and explained by a series of deductions from the persistence of force. This is the task of a Physical Synthesis, which shows the structure and functions of the nervous system to have resulted from intercourse between the organism and its environment. And thus is laid the coping-stone of a treatise which has definitively constituted Psychology a science.

With the definitive constitution of the science our inquiry, which began with the differentiation of its subject-matter, comes to an end. We have seen mind slowly emancipating itself from the barbaric Cosmos, and raised into an independent object of speculation. Once "differentiated" it begins itself to unfold, and at the same time to gather round it the at first alien facts of sensation, appetite, and bodily feeling generally. These are increasingly matter of inquiry, and theories respecting them take the hue and shape of the sciences which relate to the material world. The science of motion evolves, and the idea of orderly sequence enters into Psychology. Natural Philosophy rises from motion to force, and Psychology passes from conjunction to causation. Chemistry tears aside a corner of Nature's veil, and a shaft is sunk in a mysterious field of mind. The sciences of organic nature receive a forward impulse, and mind and life are joined in inextricable union. A philosophy of the universe, incorporating all the sciences, is created, and Psychology, while attaining increased independence as regards the adjacent sciences, is merged in that deductive science of the Knowable which has more widely divorced, and yet more intimately united, the laws of matter and of mind.— *Westminster Review.*

DISTANCES OF THE STARS.

By CAMILLE FLAMMARION.

TRANSLATED FROM THE FRENCH OF LA NATURE, BY J. FITZGERALD, A. M.

SINCE the beginning of this century, our idea of the universe has undergone a complete metamorphosis, though but few persons appear to recognize this fact. Less than a century ago, the *savants* who admitted the earth's motion (some still rejected it) pictured to

themselves the system of the universe as being bounded by the frontier of Saturn's orbit, at a distance from the central sun equal to 109,000 times the diameter of the earth, or about 860,000,000 miles. The stars were *fixed*, spherically distributed, at a distance but a little greater than that of Saturn. Beyond this limit a vacant space was supposed to surround the universe. The discovery of Uranus, in 1785, did away at once with this belt, consisting of Saturn's orbit, and the frontier of solar domination was pushed out to a distance of 1,900,000,000 miles from the centre of the system, that is to say, beyond the space which was vaguely supposed to be occupied by the stars. The discovery of Neptune, in 1846, again removed these limits to a distance that would have appalled our fathers; the orbit described by this planet being 2,862,000,000 miles from the sun.

But the attractive force of the sun extends farther still. Beyond the orbit of Uranus, beyond the dark route slowly traversed by Neptune, the frigid wastes of space are traveled over by the comets in their erratic courses. Of these, some, being controlled by the sun, do not leap from system to system, but move in closed curves, though at distances far greater than those of Uranus and Neptune. Thus Halley's comet recedes to a distance of over 3,200,000,000 miles from the sun; the comet of 1811, 36,000,000,000; and that of 1680, 75,000,000,000. The period of the last-named comet is 8,800 years.

Still these figures can scarcely be compared to those which represent the distances of the stars. What means have we of measuring these distances? Here the diameter of the earth will not serve as the base of the triangle, as when we measure the moon's distance; nor can we, as in the case of the sun, get any assistance from another planet. However, fortunately for us, the arrangement of our system affords us a means of measuring these distant perspectives; and this, while demonstrating over again the earth's motion round the sun, turns that motion to account for the solution of the greatest of astronomical problems.

In revolving round the sun, at the distance of 92,000,000 miles, the earth annually describes an ellipse of about 500,000,000 miles. The diameter of this orbit is 184,000,000 miles. As the earth's revolution round the sun is performed in a year, the earth, at any given instant, will be opposite to the point where it stood six months before, as also to the point where it will stand six months later. Here is a line of sufficient length to serve as base of a triangle the apex of which shall be a star.

The process, then, for measuring the distance of a star from the earth consists in minutely observing this star at an interval of six months, or better, for a whole year, noting whether it remains fixed, or whether it undergoes some little appreciable displacement of perspective, owing to the annual displacement of the earth around the sun. If it remains fixed, this is because it is at an infinite distance

from us—at the horizon of the heavens, so to speak—and our base-line of 184,000,000 miles is as nothing in comparison with this remoteness. But if it is displaced, then we know that it annually describes a small ellipse, corresponding to the annual revolution of the earth. Every one has remarked, while traveling by rail, how the trees and other objects near at hand move in a direction contrary to our own, their speed being greater in proportion to their nearness; whereas distant objects on the horizon remain fixed. This same effect is produced in space, in consequence of our annual motion round the sun. But though we move incomparably swifter than an express-train, our rate being 1,632,000 miles per day, and 68,000 per hour, the stars are so distant that they scarcely budge. Our 184,000,000 miles of displacement are almost nothing as concerns even the nearest of them. The inhabitants of Jupiter, Saturn, Uranus, or Neptune, with their orbits five, nine, nineteen, and thirty times as large as ours, could determine the distance of a far greater number of stars than we.

This mode of measuring the distance of the stars by the perspective effect produced by the earth's annual displacement was anticipated by the astronomers of the eighteenth century, and in particular by Bradley, who, while attempting to measure the distances of the stars by comparing together observations made at an interval of six months, discovered—something else. Instead of finding the distance of the stars on which his observations were directed, he discovered a very important optical phenomenon, viz., the *aberration of light*, the effect produced by the motion of light and the motion of the earth combined. Similarly, William Herschel, while seeking the parallaxes of the stars by comparing bright stars with their nearest neighbors, discovered the systems of double stars. So, too, Fraunhofer, while seeking the limits of the colors in the solar spectrum, discovered the absorption rays, the study of which has given rise to Spectrum Analysis. The history of the sciences shows that frequently discoveries have been made in the course of investigations which had but little to do with them directly. Columbus discovered the New World while aiming to reach the eastern coast of Asia by sailing to the west. He would never have discovered it, would never have sought for it, had he known the true distance between Portugal and Kamtchatka.

It was not till 1840 that the distance of any of the stars was ascertained. This discovery is, therefore, of recent date, and we are only now beginning to form an approximate idea of the real distances which separate us from the stars. The parallax of the star 61 in the Swan, which was the first to be determined, was ascertained by Bessel, and was the result of observations made at Königsberg from 1837 to 1840. In 1812, Arago and Mathieu had made observations on this star, but without reaching any certain results. The parallax of Alpha in the Lyre was found by Struve, in the course of observations made at Dorpat between 1835 and 1838; but it was not pub-

lished till after the year 1840. The same is to be said of Alpha in Centaur, observed in 1832 and in 1839 on the Cape of Good Hope by Henderson and Maclear; this is the nearest to us of all the stars.

There are two ways of determining these parallaxes. The first is, to compare together the positions observed at intervals of six months; the other, to discover an apparent motion in a star (as compared with a motionless star situated at a far greater distance than that which is studied): this apparent motion being due to the perspective produced by the annual revolution of the earth in its orbit. This is the method mostly employed now. Galileo, in his "Dialogues;" Gregory, in the "Proceedings of the Royal Society" (1675); Huyghens, in his "Cosmotheoros," published in 1695; Condorcet, in his "*Éloge* of Roemer," in 1773; and William Herschel, in 1781, have described both methods. Hooke, Flamstead, Cassini, Bradley, Robert Long, Herschel, Piazzi, and Brinkley, strove, from 1674 to 1820, to determine the small quantity of the apparent movement of the brightest stars, which used to be regarded as the nearest; but their efforts were fruitless, owing to the inconsiderable amount of this motion. There was need of instruments of the utmost precision, a rigid spirit of observation, and an indomitable patience, in order to get at trustworthy results.

Since 1840 the attention of astronomers has been oftentimes directed to this investigation, and thousands of calculations have been made. With great difficulty astronomers have succeeded in determining the parallaxes of *a few* stars. But the inevitable errors of observation often involve the results in obscurity. Let the reader only bear in mind that there is not *one* star that is sufficiently near to give us a parallax of *one second!* A second is the dimension to which would be reduced a circle one metre (3 ft. 3.37 in.) in diameter carried away to a distance of 206 kilometres (127.72 miles) from the eye. This appears to be less than nothing: it is equal to the thickness of a hair stretched at the distance from the eye of 20 metres (74 feet). The apparent annual movement of a star, whose distance can be known, is performed altogether within this infinitesimal space. For an observer on the star that is nearest to us, this hair would conceal the whole space between the earth and the sun.

As no star offers a parallax of one second, it follows that the nearest of the stars is distant from earth no less than 206,265 times 92,000,000 miles. The space which surrounds the planetary system is void of stars to that distance at least.

The star which is nearest to us, Alpha of Centaur, has a parallax of 0.″91. Its distance from earth is 226,400 times the radius of the earth's orbit, or 21,000,000,000,000 miles. This is our *neighbor* star, and its distance is probably the minimum distance between star and star — 21,000,000,000,000 miles. Each of these stars shines with its own light—is a sun like our own.

The second star, in the order of distances, is 61 Cygni. Its parallax is 0.″51, and its remoteness 37,000,000,000,000 miles.

Of the thousands of stars which have been studied, we know the distances of only twenty. Among these we may signalize Sirius, a sun 2,688 times larger than our own, surrounded by a system of heavenly bodies, several of which are already known, and distant from us 82,000,000,000,000 miles; the Polar Star, which is a double star, distant 292,000,000,000,000 miles; and Capella, distant 425,000,000,000,000 —a space which is traversed by light in seventy-one years and eight months; so that the luminous ray which reaches us from this fine star in 1874 must have started out in 1803! Capella might have been extinguished in 1804, but we should see it still. It might go out to-day, and yet the inhabitants of the earth would continue to admire it in their heavens until 1946. Conversely, if there existed, on the planets gravitating round Capella, minds whose transcendent vision could thence descry our little earth, lost as it is amid the sun's rays, they would now see the earth of the year 1803, and would be seventy-one years eight months behindhand in its history. These are the stars that are nearest to us. The others are incomparably more remote.

There are stars whose light cannot reach us in less than 100, 1,000, or 10,000 years, though light travels at the rate of 185,000 miles per second!

To traverse the sidereal world of which we form part (the Milky-Way), light takes 15,000 years.

To reach us from certain of the nebulæ, it must travel for 300 times that period, or 5,000,000 years.

Let the imagination, that is not appalled by these immensities, strive to conceive of them. If it does not experience the "vertigo of the infinite," let it calmly contemplate these abysses, and realize the position of the earth and of man in presence of them. Thus will it gain some conception of the discoveries made by sidereal astronomy.

Such are the dimensions actually measured in the general constitution of the universe. As yet we are only at the vestibule of the edifice, on the edge of the abyss of infinitude: and we shall never penetrate very far beyond.

FEMALE SUFFRAGE.

By Professor GOLDWIN SMITH.

MR. FORSYTH'S bill for removing the electoral disabilities of women, the second reading of which is at hand, has received less attention than the subject deserves. The residuum was enfranchised for the sake of its vote by the leaders of a party which for a series of years had been denouncing any extension of the suffrage, even to the most intelligent artisans, on the ground that it would place

political power in unfit hands. An analogous stroke of strategy, it seems, is now meditated by the same tacticians in the case of female suffrage, the motion in favor of which is brought forward by one of their supporters, and has already received the adhesion of their chief. The very foundations of society are touched when party tampers with the relations of the sexes.

In England the proposal at present is to give the suffrage only to unmarried women being householders. But the drawing of this hard-and-fast line is at the outset contested by the champions of women's rights; and it seems impossible that the distinction should be maintained. The lodger-franchise is evidently the vanishing-point of the feudal connection between political privilege and the possession of houses or land. The suffrage will become personal in England, as it has elsewhere. If a property qualification remains, it will be one embracing all kinds of property: money settled on a married woman for her separate use, as well as the house or lodgings occupied by a widow or a spinster. In the counties already, married women have qualifications in the form of land settled to their separate use; and the notion that a spinster in lodgings is specially entitled to the suffrage, as the head of a household, is one of those pieces of metaphysics in which the politicians who affect to scorn any thing metaphysical are apt themselves unwarily to indulge. If the present motion is carried, the votes of the female householders, with that system of election pledges which is now enabling minorities, and even small minorities, to control national legislation, will form the crow-bar by which the next barrier will be speedily forced.

Marriage itself, as it raises the position of a woman in the eyes of all but the very radical section of the Woman's Right party, could hardly be treated as politically penal. And yet an act conferring the suffrage on married women would probably be the most momentous step that could be taken by any legislature, since it would declare the family not to be a political unit, and for the first time authorize a wife, and make it in certain cases her duty as a citizen, to act publicly in opposition to her husband. Those at least who hold the family to be worth as much as the state will think twice before they concur in such a change.

With the right of electing must ultimately go the right of being elected. The contempt with which the candidature of Mrs. Victoria Woodhull for the presidency was received by some of the advocates of female suffrage in America only showed that they had not considered the consequences of their own principles. Surely she who gives the mandate is competent herself to carry it. Under the parliamentary system, whatever the forms and phrases may be, the constituencies are the supreme arbiters of the national policy, and decide not only who shall be the legislators, but what shall be the course of legislation. They have long virtually appointed the ministers, and now they ap-

point them actually. Twice the Government has been changed by a *plébiscite*, and on the second occasion the budget was submitted to the constituencies as directly as ever it was to the House of Commons. There may be some repugnance, natural or traditional, to be overcome in admitting women to seats in Parliament; but there is also some repugnance to be overcome in throwing them into the turmoil of contested elections, in which, as soon as female suffrage is carried, some ladies will unquestionably claim their part.

There are members of Parliament who shrink from the step which they are now urged to take, but who fancy that they have no choice left them because the municipal franchise has already been conceded. The municipal franchise was no doubt intended to be the thin end of the wedge. Nevertheless there is a wide step between this and the national franchise; between allowing female influence to prevail in the disposition of school-rates, or other local rates, and allowing it to prevail in the supreme government of the country. To see that it is so, we have only to imagine the foreign policy of England determined by the women, while that of other countries is determined by the men; and this in the age of Bismarck.

The writer of this paper himself once signed a petition for female household suffrage got up by Mr. Mill. He has always been for enlarging the number of active citizens as much as possible, and widening the basis of government, in accordance with the maxim, which seems to him the sum of political philosophy, "That is the best form of government which doth most actuate and dispose all parts and members of the commonwealth to the common good." He had not, when he signed the petition, seen the public life of women in the United States. But he was led to reconsider what he had done, and prevented from going further, by finding that the movement was received with mistrust by some of the best and most sensible women of his acquaintance, who feared that their most valuable privileges, and the deepest sources of their happiness, were being jeopardized to gratify the political aspirations of a few of their sex. For the authority of Mr. Mill, in all cases where his judgment was unclouded, the writer felt and still feels great respect. But, since that time, Mr. Mill's autobiography has appeared, and has revealed the history of his extraordinary and almost portentous education, the singular circumstances of his marriage, his hallucination (for it surely can be called nothing less) as to the unparalleled genius of his wife, and peculiarities of character and temperament such as could not fail to prevent him from fully appreciating the power of influences which, whatever our philosophy may say, reign and will continue to reign supreme over questions of this kind. To him marriage was a union of two philosophers in the pursuit of truth; and, in his work on the position and destiny of women, not only does he scarcely think of children, but sex and its influences seem hardly to be present to his mind. Of the distinctive excellence

and beauty of the female character it does not appear that he had formed any idea, though he dilates on the special qualities of the female mind.

Mr. Mill has allowed us to see that his opinions as to the political position of women were formed early in his life, probably before he had studied history rationally, perhaps before the rational study of history had even come into existence. The consequence, with all deference to his great name be it said, is that his historical presentment of the case is fundamentally unsound. He and his disciples represent the lot of the woman as having always been determined by the will of the man, who, according to them, has willed that she should be the slave, and that he should be her master and her tyrant. "Society, both in this" (the case of marriage) "and other cases, has preferred to attain its object by foul rather than by fair means; but this is the only case in which it has substantially persisted in them even to the present day." This is Mr. Mill's fundamental assumption; and from it, as every rational student of history is now aware, conclusions utterly erroneous as well as injurious to humanity must flow. The lot of the woman has not been determined by the will of the man, at least in any considerable degree. The lot both of the man and the woman has been determined from age to age by circumstances over which the will of neither of them had much control, and which neither could be blamed for accepting or failing to reverse. Mr. Mill, and those who with him assume that the man has always willed that he should himself enjoy political rights, and that the woman should be his slave, forget that it is only in a few countries that man does enjoy political rights; and that, even in those few countries, freedom is the birth almost of yesterday. It may probably be said that the number of men who have really and freely exercised the suffrage up to the present time is not much greater than the number of those who have in different ages, and in various ways, laid down their lives or made personal sacrifices of other kinds in bringing the suffrage into existence.

In the early stages of civilization the family was socially and legally as well as politically a unit. Its head represented the whole household before the tribe, the state, and all persons and bodies without; while within he exercised absolute power over all the members, male as well as female, over his sons as well as over his wife and daughters. On the death of the head of a family his eldest son stepped into his place, and became the representative and protector of the whole household, including the widow of the deceased chief. This system, long retained in conservative Rome, was there the source of the national respect for authority, and, by an expansion of feeling from the family to the community, of the patriotism which produced and sustained Roman greatness. But its traces lingered far down in history. It was not male tyranny that authorized a Tudor queen to send members of the royal household to the Tower by her personal

authority as the mistress of the family, without regard to the common law against arbitrary imprisonment. Such a constitution was essential to the existence of the family in primitive times; without it, the germs of nations and of humanity would have perished. To suppose that it was devised by the male sex for the gratification of their own tyrannical propensities would be most absurd. It was at least as much a necessity to the primitive woman as it was to the primitive man. It is still a necessity to woman in the countries where the primitive type of society remains. What would be the fate of a female Bedouin, if she were suddenly invested with woman's rights and emancipated from the protection of her husband?

That the present relation of women to their husbands literally has its origin in slavery, and is a hideous relic of that system, is a theory which Mr. Mill sets forth in language such as, if it could sink into the hearts of those to whom it is addressed, would turn all affection to bitterness, and divide every household against itself. Yet this theory is without historical foundation. It seems, indeed, like a figure of invective heedlessly converted into history. Even in the most primitive times, and those in which the subjection of the women was most complete, the wife was clearly distinguished from the slave. The lot of Sarah is different from that of Hagar; the authority of Hector over Andromache is absolute, yet no one can confound her position with that of her handmaidens. The Roman matron who sent her slave to be crucified, the Southern matron who was the fierce supporter of slavery, were not themselves slaves. Whatever may now be obsolete in the relations of husband and wife is not a relic of slavery, but of primitive marriage, and may be regarded as at worst an arrangement once indispensable which has survived its hour. Where real slavery has existed, it has extended to both sexes, and it has ceased for both at the same time. Even the Oriental seclusion of women, perhaps the worst condition in which the sex has ever been, has its root, not in the slave-owning propensity so much as in jealousy, a passion which, though extravagant and detestable in its excessive manifestation, is not without an element of affection. The most beautiful building in the East is that in which Shah Jehan rests by the side of Nourmahal.

If the calm and philosophic nature of Mr. Mill is ever betrayed into violence, it is in his denunciations of the present institution of marriage. He depicts it as a despotism full of mutual degradation, and fruitful of no virtues or affections except the debased virtues and the miserable affections of the master and the slave. The grossest and most degrading terms of Oriental slavery are used to designate the relations of husband and wife throughout the whole book. A husband who desires his wife's love is merely seeking "to have, in the woman most nearly connected with him, not a forced slave, but a willing one—not a slave merely, but a favorite." Husbands have, therefore "put every thing in practice to enslave the minds of their wives." If a wife is intensely

attached to her husband, "exactly as much may be said of domestic slavery. . . . It is part of the irony of life that the strongest feelings of devoted gratitude of which human nature seems to be susceptible are called forth in human beings toward those who, having the power entirely to crush their earthly existence, voluntarily refrain from using their power." Even children are only links in the chain of bondage. By the affections of women "are meant the only ones they are allowed to have—those to the men with whom they are connected, or to the children who constitute an additional and indefeasible tie between them and a man." The Jesuit is an object of sympathy because he is the enemy of the domestic tyrant, and it is assumed that the husband can have no motive but the love of undivided tyranny for objecting to being superseded by an intriguing interloper in his wife's affections. As though a wife would regard with complacency, say a female spiritualist, installed beside her hearth! It is impossible to doubt that Mr. Mill's views, in writing such passages, were colored by the incidents of his life. But it is by circulating his book and propagating his notions that the petitions in favor of female suffrage have been obtained.

The anomalies in the property law affecting married women, to which remedial legislation has recently been directed, are like whatever is obsolete in the relations between the sexes generally, not deliberate iniquities, but survivals. They are relics of feudalism, or of still more primitive institutions incorporated by feudalism; and, while the system to which they belonged existed, they were indispensable parts of it, and must have been so regarded by both sexes alike. Any one who is tolerably well informed ought to be ashamed to represent them as the contrivances of male injustice. It is not on one sex only that the relics of feudalism have borne hard.

The exclusion of women from professions is cited as another proof of constant and immemorial injustice. But what woman asked or wished to be admitted to a profession fifty or even five-and-twenty years ago? What woman till quite recently would have been ready to renounce marriage and maternity in order that she might devote herself to law, medicine, or commercial pursuits? The fact is, the demand is connected with an abnormal and possibly transient state of things. The expensiveness of living, in a country where the fashion is set by millionaires, combined with the overcrowded condition of the very callings to which women are demanding admission, has put extraordinary difficulties in the way of marriage. Many women are thus left without an object in life, and they naturally try to open for themselves some new career. The utmost sympathy is due to them, and every facility ought in justice to be afforded them; though unhappily the addition of fresh competitors for subsistence, to a crowd in which literally famine has already been at work, will be as far as possible from removing the real root of the evil; to say nothing of the risk which a woman must run in committing herself irrevocably to a precarious calling and

closing against herself the gate of domestic life. But the demand, as has been already said, is of yesterday, and probably in its serious form is as yet confined to the countries in which the special impediments to early marriages exist. In the United States it is not easy to distinguish the serious demand from a passion for emulating the male sex which has undoubtedly taken possession of some of the women there, as it took possession of women under the Roman Empire, who began to play the gladiator when other excitements were exhausted. With regard to the profession of law, indeed, so far as it is concerned with the administration of justice, there is, and, while human emotions retain their force, always will be, a reason, independent of the question of demand, for excluding women, at least for excluding one of the two sexes. The influence of a pretty advocate appealing to a jury, perhaps in behalf of a client of her own sex, would not have seemed to Mr. Mill at all dangerous to the integrity of public justice; but most people, and especially those who have seen any thing of sentimental causes in the United States, will probably be of a different opinion.

What has been said as to the professions is equally true of the universities, which, in fact, were schools of the professions. A few years ago, what English girl would have consented to leave her home and mingle with male students? What English girl would have thought it possible that she could go through the whole of the medical course with male companions of her studies? Even now, what is the amount of settled belief in the right, as it is termed, of "coeducation?" What would be said to a young man if he presented himself in the name of that right at the door of Vassar, or any female college? Without arraigning the past, those whose duty it is may consider, with the deliberation which they deserve, the two distinct questions, whether it is desirable that the education of both sexes shall be the same, and whether it is desirable that the young men and the young women of the wealthier classes shall be educated together in the same universities. Beneath the first probably lies the still deeper question whether it is good for humanity that woman, who has hitherto been the helpmate and the complement, should become, as the leaders in the woman's right movement in the United States evidently desire, the rival and competitor of man. Both she cannot be; and it is by no means clear that, in deciding which she shall be, the aspirations of the leaders of this movement coincide with the interests of the sex.[1]

If the education of women has hitherto been defective, so has that of men. We are now going to do our best to improve both. Surely no accomplishment in the acquisition of which woman has been condemned to spend her time could well be less useful than that of writ-

[1] The question of female education is not here discussed. But the arbiters of that question will do well to bear in mind that the happiness of most women materially depends on their having healthy children; and that children are not likely to be healthy if the brains of both parents are severely tasked.

ing Greek and Latin verses. That the comparative absence of works of creative genius among women is due entirely to the social tyranny which has excluded, or is supposed to have excluded, them from literary and scientific careers, cannot be said to be self-evident. The case of music, often cited, seems to suggest that there is another cause, and that the career of intellectual ambition is in most cases not likely to be happier than that of domestic affection, though this is no reason why the experiment should not be fairly tried. Perhaps the intellectual disabilities under which women have labored, even in the past, have been somewhat exaggerated. If Shelley was a child to Mrs. Mill, as Mr. Mill says, no "social disabilities" hindered Mrs. Mill from publishing poems which would have eclipsed Shelley. The writer once heard an American lecturer of great eminence confidently ascribe the licentiousness of English fiction in the early part of the last century to the exclusion of women from literary life. The lecturer forgot that the most popular novelist of that period, and certainly not the least licentious, was Mrs. Aphra Behn. And this lady's name suggests the remark that as the relations of the sexes have been the most intimate conceivable, the action of character has been reciprocal, and the level of moral ideas and sentiments for both pretty much the same.

Mr. Mill, seeing that the man is the stronger, seems to assume that the relations between man and woman must always have been regulated simply by the law of the strongest. But strength is not tyranny. The protector must always be stronger than the person under his protection. A mother is overwhelmingly superior in strength to her infant child, and the child is completely at her merey. The very highest conception that humanity has ever formed, whether it be founded in reality or not, is that of power losing itself in affection. This may be said without lapsing into what has been called the religion of inhumanity. St. Paul (who on any hypothesis is an authoritative expositor of the morality which became that of Christendom) preaches fraternity plainly and even passionately enough. He affirms with the utmost breadth the essential equality of the sexes, and their necessary relations to each other as the two halves of humanity. Yet he no less distinctly ratifies the unity of the family, the authority of its head, and the female need of personal government; a need which, when it is natural, has nothing in it more degrading than the need of protection.

The "Revolt of Woman" is the name given to the movement by a female writer in America, who, by-the-way, claims, in virtue of "superior complexity of organization," not only political equality, but absolute supremacy over man. But, in this revolt, to what do the insurgents appeal? To their own strength, or to the justice and affection of man?

The main factors of the relation between the sexes have hitherto been, and probably still are, natural affection—the man's need of a

helpmate, the woman's need of a protector and provider, especially when she becomes a mother, and the common interest of parents in their children. One of these factors must be withdrawn, or greatly reduced in importance, to warrant us in concluding that a fundamental change in the relation is about to take place. Mr. Mill hardly notices any one of the four, and he treats the natural relation which arises from them as a purely artificial structure, like a paper constitution or an act of Parliament, which legislatures can modify or abolish at their pleasure.

It has no doubt been far from a satisfactory world to either sex; but unless we attach a factitious value to public life and to the exercise of public professions, it will be very difficult to prove that it has been more unsatisfactory for one sex than the other. If the woman has had her sorrows at home, the man has had his wars and his rough struggles with Nature abroad, and with the sweat of his brow he has reclaimed the earth, and made it a habitation for his partner as well as for himself. If the woman has had her disabilities, she has also had her privileges. War has spared her; for, if in primitive times she was made a slave, this was better, in the days before sentiment at least, than being massacred. And her privileges have been connected with her disabilities. If she had made war by her vote, she could not have claimed special respect as a neutral, nor will she be able to claim special respect as a neutral if she makes war by her vote hereafter.

In the United States the privileges of women may be said to extend to impunity, not only for ordinary outrage, but for murder. A poisoner, whose guilt has been proved by overwhelming evidence, is let off because she is a woman; there is a sentimental scene between her and her advocate in court, and afterward she appears as a public lecturer. The whiskey crusade shows that women are practically above the law. Rioting, and injury to the property of tradesmen, when committed by the privileged sex, are hailed as a new and beneficent agency in public life; and because the German population, being less sentimental, asserts the principles of legality and decency, the women are said to have suffered martyrdom. So far from the American family being the despotism which Mr. Mill describes, the want of domestic authority lies at the root of all that is worst in the politics of the United States. If the women ask for the suffrage, say some American publicists, they must have it; and in the same way every thing that a child cries for is apt to be given it, without reflection as to the consequences of the indulgence.

There is therefore no reason for setting the sexes by the ears, or giving to any change which it may be just and expedient to make the aspect of a revolt. We may discuss on its own merits the question whether female suffrage would be a good thing for the whole community. The interest of the whole community must be the test. As to natural rights, they must be sought by those who desire them, not

in communities, but in the primeval woods, where the available rights of women will be small.

The question whether female suffrage on an extended scale is good for the whole community is probably identical, practically speaking, with the question whether it is good for us to have free institutions or not. Absolute monarchy is founded on personal loyalty. Free institutions are founded on the love of liberty, or, to speak more properly, on the preference of legal to personal government. But the love of liberty and the desire of being governed by law alone appear to be characteristically male. The female need of protection, of which, so long as women remain physically weak, and so long as they are mothers, it will be impossible to get rid, is apparently accompanied by a preference for personal government, which finds its proper satisfaction in the family, but which gives an almost uniform bias to the political sentiments of women. The account commonly accepted, of the reactionary tendency which all admit to be generally characteristic of the sex, is, that they are priest-ridden. No doubt many of them are priest-ridden, and female suffrage would give a vast increase of power to the clergy. But the cause is probably deeper and more permanent, being, in fact, the sentiment inherent in the female temperament, which again is formed by the normal functions and circumstances of the sex. And, if this is the case, to give women the franchise is simply to give them the power of putting an end, actually and virtually, to all franchises together. It may not be easy to say beforehand exactly what course the demolition of free institutions by female suffrage would take. In the United States probably some woman's favorite would be elected President, and reëlected till his power became personal, and perhaps dynastic. But there can be little doubt that in all cases, if power were put into the hands of women, free government, and with it liberty of opinion, would fall.

In France, it is morally certain that at the present moment, if votes were given to the women, the first result would be the restoration to power of the Bourbons, with their reactionary priesthood, and the destruction of all that has been gained by the national agonies of the last century. The next result would be a religious crusade against German Protestantism and Italian freedom.

But would the men submit? Would they, in compliance with the edict of the women, and in obedience to a woman's government, haul down the tricolor, hoist the white flag, bow their necks to the yoke of reaction, and march against the victors of Sedan in a cause which they detest? This question points to another serious consideration. It is true that law is much stronger now than it was in primitive or feudal times, and a woman is more under its protection and less under the private protection of her husband and her kinsmen. But law, after all, though the fact may be rough and unwelcome, rests at bottom on the force of the community, and the force of the community is

male. No woman can imagine that her sex can execute, or in case of rebellion reassert, the law; for that they must look entirely to the men. The men would be conscious of this, and, if any law were made exclusively in the interest of the women, and in contradiction to the male sense of justice, they would refuse to carry it into effect. In the United States there have been intimations, on the part of the women, of a desire to make a very lavish use of capital punishment, untrammeled by the technical rules of evidence, for offenses or supposed offenses against the sex. The men would, of course, refuse execution; law would be set at defiance, and government would be overturned. But the bad effects of the public consciousness that executive force—the rude but indispensable basis of law—had been partly removed, and that the law was being made by those who had not the power to carry it into effect, would not be limited to manifest instances of the influence of sex in legislation. In cases where, as in Jamaica, an elective government has rested on two races, equal, legally speaking, in political power, but of which one was evidently inferior in real force to the other, reverence for law has been weak, and the result has been disastrous. There can be little doubt that, as soon as the Federal bayonets are removed, there will be another case of the same kind in the Southern States; laws made by negro majorities will be set at defiance by the stronger race. To personal despotism or class domination civilization can put an end, but it cannot eliminate force.

It is very likely that in England the women, to reform drunken husbands, would vote for extreme prohibitory measures against liquor; but the difficulty of carrying such legislation into effect, great as it is already, could hardly fail to be much increased by the feeling that it was the act of the women, and the consequence would probably be contempt, and perhaps open defiance, of the law. Female legislation with regard to education, in the interest of clerical ascendency, would be apt to be attended by the same effects.

Elective government, with the liberty of opinion and the power of progress which are its concomitants, has been brought into existence by the most terrible throes of humanity. When perfected and firmly established, it will, as we hope, and have good grounds for believing, give to reason and justice an ascendency which they have never had before in human affairs, and increase the happiness of all by making private interest subordinate to the public good. But its condition, if we look at the world as a whole, is still exceedingly precarious. All the powers of class interest, of sybaritism, of superstition, are arrayed against it, and have vast forces at their command, including the great standing armies of Europe, while they find accomplices in the lassitude, the alarm, the discouragement caused by the revolutionary storms which, unhappily, are almost inevitable attendants upon the birth of a new order of things. Its existence having been so far a

struggle, and an assertion at the sword's point, of principles, just in themselves, but needing qualification to make them available as the foundations of a polity, it is full of defects, to remedy which, so as to make it the deliberate expression of public reason, clear of sectional interest and passion, is now the great aim of political thought and effort. Those to whose hands it is committed at this crisis are trustees for posterity of a heritage bought by ages of effort and torrents of blood; and they are bound to allow neither their own ambition nor that of any one else, if they can help it, to imperil the safety of their trust. That women would be likely to vote for one set of aspirants to political office rather than for the opposite set, would be a very bad reason for withholding from them the suffrage even for a day; but, that they would probably overturn the institutions on which the hopes of the world rest, is as good a reason as there can be for withholding any thing from anybody. When free institutions are firmly established in Europe, the question of female suffrage may perhaps be raised with less peril, so far as political interests are concerned; but, to take a female vote on their fate at present, would be as suicidal as it would have been to take a female vote on the issues between Charles I. and the Parliament in the middle of the Civil War.

So far as elective government has succeeded, women in general have fully reaped the benefit of the improvements, moral and material, which it has produced. They are mistaken if they imagine that they fared better under the form of government which, in France and elsewhere, if they had the power, their sentiment would lead them to restore. They were not exempt from the misery and starvation brought into every home by the ambitious wars and the general misrule of the monarchies or even from the cruelty of their criminal laws. Down to the last days of the monarchy in France women as well as men were broken alive upon the wheel for theft.

It is needless to say that any discussion of the relative excellence, intellectual or moral, of the two moieties of humanity would be equally barren and irrelevant. The only question is as to the proper spheres of the man and woman; and assuredly, by unsexing women, we should do no homage to their sex.

It is alleged that female influence would mitigate the violence of party politics. But what ground have we, in reason or experience, for believing that women, if introduced into the political arena, would be less violent than men? Hitherto they have been free from political vices, because they have generally taken no part in politics, just as home has been an asylum from political rancor, because political division has not been introduced between man and wife. But the chances are, that, being more excitable, and having, with more warmth and generosity of temperament, less power of self-control, women would, when once engaged in party struggles, be not less but more violent than men. All our experience, in fact, points this way. In

the Reign of Terror, and in the revolt of the Commune, the women notoriously rivaled the men in fury and atrocity. The same was the case in the late American Civil War. What has been the effect of public life on the character of the women who have thrown themselves into it in the United States can be doubted by no human being; and our experience of female agitations in this country seems to tell pretty much the same tale. That party politics require mitigation, and perhaps something more, may be readily admitted; but we are not likely to make the caldron boil less fiercely by flinging into it female character and home.

That home would escape disturbance it is surely difficult to believe. We are told that a difference of religion between man and wife does not produce unhappiness. The fact may be doubted when the difference is strong. But religion is an affair of the other world; and it does not, at all events it need not, bring people into direct, much less into public collision in this world. A man and his wife, taking opposite sides in politics, would be brought into direct and public collision, especially if they happened to be active politicians, about a subject of the most exciting kind. Would the harmony of most households bear the strain? Would not a husband who cared for his own happiness be apt to say that if his wife wanted it she might have the vote, but that there should be only one vote between them?

Men are not good house-keepers, and there need not be any thing disparaging in saying that women, as a rule, are not likely to be good politicians. Most of them, after all, will be married, and their sphere will be one in which they do not directly feel the effects of good or bad government, which are directly felt by the man who goes forth to labor, and the practical sense of which, more than any thing else, forms the political wisdom, such as it is, of the great mass of mankind. Nor would there be any thing, generally speaking, to balance the judgment, as it is balanced in men by the variety of practical needs and considerations. Even with male constituencies, particular questions are apt to become too predominant, and to lead to the exaction of tyrannical pledges and to narrow ostracism of conscientious public men. But with female suffrage there would probably be always a woman's question, of a kind appealing to sentiment, such as the question of the contagious diseases act, which demagogues would take care to provide, and which would swallow up every other question, and make a clean sweep of all public men who might refuse to take the woman's pledge. With female suffrage, the question of the contagious diseases act would probably have made a clean sweep, at the last general election, of all the best servants of the state.

Mr. Mill had persuaded himself that great capacity for government had been displayed by women, and that there was urgent necessity for bringing them into the management of the state. But he can hardly be serious when he cites as an instance of female rule a constitutional

queen whose excellence consists in never doing any act of government except under the guidance of her ministers. The queens regnant or consort, before our monarchy became constitutional, who may be said to have wielded power, are the Empress-Queen Matilda, Eleanor, the wife of Henry II., Isabella, the wife of Edward II., Margaret of Anjou, Mary, Elizabeth, and Henrietta Maria. Not much can be made of this list, when it is considered that both Margaret of Anjou and Henrietta Maria were, by their temper, principal causes of civil wars, and that the statesmanship of Elizabeth has totally collapsed between Mr. Froude's first volume and his last, while her feminine relations with Leicester and other favorites have contracted a much more ominous complexion in a political as well as in a moral point of view. On the other hand, it is probable that Eleanor, the wife of Edward I., and certain that Caroline, the wife of George II., rendered, in a womanly way, high services to the state. Mr. Mill says, from his experience at the India office, that the queens in India are better than the kings. But the reason is obvious. British protection has suspended the operation of the rude checks on the vices of Indian despots, and a woman brought up in the *zenana*, though she cannot possibly be a good ruler, may well be better than a hog or a tiger.

Neither the cases of queens, however, nor those of female regents of the Netherlands, to which Mr. Mill gives so strange a turn (as though Charles V. and Philip II. had preferred females on account of their ability to male members of the house), are in point. They all belong to the hereditary system, under which these ladies were called to power by birth or appointment, and surrounded by counselors from whose policy it is scarcely possible to distinguish that of the sovereign. Under the elective system, women would have to make their own way to seats in Parliament and to office by the same means as male politicians, by canvassing, stumping, wrestling with competitors in debate; and the female character would be exposed to influences entirely different from those which operated on Isabella of Castile.

Without pressing the argument against "premiers in the family way" too far, it may safely be said that the women who would best represent their sex, and whose opinions would be worth most, would be generally excluded from public life by conjugal and maternal duty. Success with popular constituencies would probably fall to the lot, not of the grave matrons and spinsters whom Mr. Mill evidently has in view, but of dashing adventuresses, whose methods of captivating their constituents would often be by no means identical with legislative wisdom, or calculated to increase our veneration for their sex.

Mr. Mill is the real father of the whole movement; the arguments of its other champions are mere reproductions of his. Whatever biased his mind, therefore, ought to be carefully noted; and again it must be said that he was possessed by an illusion—an illusion beautiful and touching, but still an illusion—as to the political genius of his wife.

He has given us the means of judging of her speculative powers, and even they, it is evident, were not extraordinarily high.

That there are women eminently capable of understanding and discussing political questions nobody will deny. These will find a sphere in the press, through which many men exercise a power which makes it a matter of indifference whether they have a vote or not. But it by no means follows that it is expedient to put political power into the hands of the whole sex; much less that it is expedient to do so at a moment when it is morally certain that they would use their power to cancel a good deal of what has been done in their interest, as well as in that of their partners, by the efforts of the last two hundred years.

Some supporters of the movement flatter themselves that women would always vote for peace, and that female suffrage would consequently be a short method of ridding the world of war and standing armies. Such experience as we have hardly warrants this anticipation. Female sovereigns, as a rule, have not been eminently pacific. It would be difficult to find four contemporary male rulers who made more wars than Catherine II. of Russia, Maria Theresa, Madame de Pompadour (who ruled France in the name of her lover), and the Termagant, as Carlyle calls her, of Spain. It is widely believed that the late Empress of the French, inspired by her Jesuits, was a principal mover in the attack on Germany. Those who know the Southern States say that the women there are far more ready to renew the Civil War than the men. The most effective check on war is, to use the American phrase, that every one should do his own fighting. But this check cannot be applied to women, who will be comparatively irresponsible in voting for war. A woman, in fact, can never be a full citizen in countries where, as in Germany, it is part of a citizen's duty to bear arms.

Finally, it is said that there are certain specific grievances under which women labor, and which call for immediate redress, but of which redress cannot be had unless women are empowered to extort it from their husbands and brothers at the polls. Of course, if there is wrong, and wrong to half humanity, which cannot be righted in any other way, we must at once accept female suffrage, whatever perils it may entail.

In the United States the grievance of which most is heard is the tyrannical stringency of the marriage tie, which, it is alleged, gives a man property in a woman, and unduly interferes with the freedom and genuineness of affection. Some of the language used is more startling than this, and if reproduced might unfairly prejudice the case. But male Legislatures in the United States have already carried the liberty of divorce so far, that the next step would be the total abolition of marriage and the destruction of the family. The women themselves have now, it is said, begun to draw back. They have

probably become aware that liberty of divorce must be reciprocal, that marriage is preëminently a restraint placed on the passions of the man in the interest of the woman, that a woman loses her charms more easily than she loses her need of a protector, and that to the children divorce is moral and social ruin. Mr. Mill demands for the "slave" the privilege of changing her master; he forgets that he would, at the same time, give the master the privilege of changing his slave.

The question, of which more is heard here, as to the right of women to the control of their own property, was one the importance of which was not likely to be fully perceived while comparatively few women earned their own bread. However, now that it is perceived, the British Legislature has at least gone so far in removing anomalies that it need not despair of seeing itself do complete justice. In the United States, male Legislatures, so far from being unwilling, display almost an exaggerated propensity to sever the interest of the wife from that of the husband. An eminent American jurist told the writer that he knew a case in which a woman was compelling her husband to work for her as a hired laborer, and another in which a woman had accomplished a divorce by simply shutting the door of the house, which was her own property, in her husband's face. After all, it must be remembered that the man remains responsible for the maintenance of the woman and her children, and that the analogy of a commercial partnership, which is in vogue with the champions of woman's right in the United States, is very far from holding good: commercial justice between themselves and their husbands is not what the women really want. It must be remembered, too, that the male has, by nature, certain advantages over the female which no legislature on earth can annul; and that it is necessary in the interest of both sexes, but especially in the interest of woman, to render the restraint of marriage acceptable, not only to persons of cultivated sensibility, but to ordinary men. If the ideal of marriage which floats in the pages of Mr. Mill were actually embodied in legislation, and the husband were stripped of all conjugal rights, and left with nothing but the responsibility of maintaining the family, it is at least possible that the result among the coarser masses of mankind might be the increase of license and the consequent degradation of women.

It is commonly said in the United States, by the Woman's Right party, that women are underpaid for their labor, and a vague hope is held out that this might be set right by female legislation. In most fields of industry women are new-comers, and on all new-comers old custom is apt at first to bear hard. Female singers, piano-forte players, novelists, painters, milliners, are not underpaid. If female clerks and school-mistresses are paid less than male clerks and school-masters, this may be partly because continuance in the calling is an element of value, and women are taken off by marriage. That a New-Yorker will persist, out of regard for the aristocracy of sex, in paying

a man a high price for his labor when he can get the work done as well for less money by a woman, is not much to be apprehended. But that Legislatures, male or female, could equalize wages, few will be credulous enough to believe, though it is possible that the attempt might be made.

As to domestic cruelty, if it can be stopped by any extension of the criminal law, there is surely not the slightest reason for believing that male Legislatures are unwilling to perform that duty; though, of course, criminal legislation in this case, as in all others, to be effective, must keep terms with reason and justice. In fact, in this matter, women are probably better in the present hands than they would be in their own. The source of these infamies and horrors in ninety-nine cases out of a hundred is drink; and if the member for Marylebone, instead of tampering with the relations between the sexes, will turn his mind to the improvement and extension of the legislation commenced under the late Government against intemperance, he will deserve, in the highest degree, the gratitude of women in general, and especially of those who have the greatest claim to our sympathy.

The case of women is not that of an unenfranchised class, the interest of which is distinct from that of the enfranchised. The great mass of them are completely identified in interest with their husbands, while even those who are not married can hardly be said to form a class, or to have any common interest, other than mere sex, which is liable to be unfairly affected by class legislation. There is therefore no reason why Parliament should not do justice in any practical question relative to the rights of women which may be brought before it, as it has already done justice in several such questions, without invoking upon itself the coercion of female suffrage.—*Macmillan's Magazine.*

A BABY-FOX.

By Dr. BURT G. WILDER.

MY readers may have heard of the artist who, finding that his portrait of the "king of beasts" was not often recognized, indignantly wrote beneath it, "This is the picture of a lion." Something of like necessity exists with reference to the figure in the present article; for it is doubtful whether any one, not already familiar with fox-babies, would recognize it as the picture of one; to use the words of another, this is an "odd, snub-nosed little creature, resembling almost any animal rather than a fox." [1]

Yet the non-recognition cannot, in this case, be ascribed to any

[1] Wood's "Illustrated Natural History of Mammalia," p. 334; it is not often that so compact an expression occurs in these usually verbose volumes.

defect in the representation; for the original drawing was made by an anatomist,[1] and engraved by one[2] whose previous work upon natural history objects has convinced him of the need for accuracy and restraint of the artistic imagination.

Certainly the non-resemblance of the little one to its mother would have been enough to shake my belief in the statement of relationship, had not both the specimens and the statement come together from a naturalist[3] who received them direct from the hunters; and my first impulse was to publish the figure *incognito*, as a zoological conundrum.

The most obvious difference is in color: the throat and chest of the old fox are whitish, also the tip of the tail; the back of the ears, the front and outer surface of the paws to near the elbows and knees, are black, and there are scattered black hairs on the tail; the rest of the body is reddish brown; and as a whole the animal would be called a "*red* fox," although a stripe across the shoulders of a darker red might entitle it to the name of "cross" fox. Now, at first sight,

[1] My friend and former pupil, Dr. W. S. Barnard.

[2] Mr. Philip Barnard, of Chicago, now a student in Cornell University.

[3] Dr. J. T. Rothrock, of Wilkesbarre, Pennsylvania, now attached to one of the United States surveying expeditions.

all the young would be called "black," although the head and shoulders are brownish, and the tail is tipped with white.

In this connection it is to be noted that Audubon and Bachman [1] had once a mother and a litter of seven young foxes; the former was nearly jet black, with the tip of the tail white; three of the young were said to be black, the other four red; one of the blackest was kept alive for six months, and as it grew older the less it became like the "black," and the more like the "cross" fox; whence they conclude that both the "cross" and "black" foxes are mere varieties of the "red;" in this opinion Mr. J. A. Allen concurs.[2]

But there is something more to be said of *our* little fox and its mother: a closer examination of the former shows that there are two kinds of hair corresponding to the two colors; the body and tail, and upper parts of the legs, are thickly covered with a kind of soft wool, of a smoke-color, but the head presents longer and reddish-colored hairs; and these same hairs are scattered over the body, more thickly in front than behind; the two kinds are as thick brush-wood and saplings; under the microscope they are even more unlike; for the "wool" is crinkled, and its texture very transparent; the pith seeming to be divided by transverse partitions into a single row of nearly square spaces; the hairs, on the other hand, are straight, and two or three times as thick, and their texture much more dense, apparently from a crowding of the partitions and interspaces; and one thing more, the hairs are reddish only as far as they project above the wool, the deeper portions, like the wool, being smoke-colored. Now, the same is the case in the old fox, with this difference, that the hairs are so long and so numerous as to completely hide the woolly coat, and so give their own color to the animal; the wool presents the same appearance under the microscope as in the young one, and seems to be little if any larger, but the hairs are at least ten times as thick at their base, and taper thence gradually to the tip. We may easily imagine, then, not only that in some cases the long hairs themselves might be black throughout, but also that, as in the case mentioned by Audubon, an increase of the number of reddish-tipped hairs during growth might convert an apparently black fox into a red one.[3]

Finally, it is certain that, were the old fox to lose her hairs and retain only the wool, she would be as black as her young, excepting, perhaps, upon the head.

After the color, the next most striking difference between the old and young foxes is the *form of the head:* that of the former is remarkable for its length, and for the total lack of *forehead*, the up-

[1] "Quadrupeds of North America," vol. i., pp. 52, 53.

[2] "Catalogue of the Mammals of Massachusetts;" "Bulletin of the Museum of Comparative Zoology," No. 8.

[3] In the "Natural History of the State of New York," De Kay says (p. 45) that the young are at first covered by smoke-brown fur.

per surface being all on a level from the tip of the nose to the top of the head; while the frontal region of the young is quite prominent. The change in the form of the head is better shown by a comparison of measurements:

	Young.	Old.
Distance from tip of muzzle to a point between the ears.....	.050,[1]	.150,
Distance from tip of muzzle to a point between the eyes.....	.022,	.075,
Width of the head opposite the eyes.....	.042,	.075,

From the above we see that in the adult fox the muzzle proper is half the length of the head from the ears forward, and that the width of the muzzle from its base (opposite the eyes) is equal to its length; while in the young the length of the muzzle is less than half the length of the head from the ears, and little more than half the width of its base; so that even without the figure we should see the justice of Wood's description of the little fox as "snub-nosed."

But the figure or the specimen itself would be required to corroborate his other remark, that it "resembles almost any other animal rather than a fox."

Now, it certainly does not resemble a fox; and among dogs it could be compared only to the young, or to some of the smaller breeds. But it does remind one irresistibly of certain dog-faced monkeys or baboons; and to some degree, as Dr. Barnard suggests, of the lemurs. In either case it is worth while to bear in mind that the gap, hitherto supposed to exist between the *Carnivora* and the *Quadrumana*, has been partly bridged over by the researches of Milne-Edwards upon the "Embryology of the *Lemuridæ*;"[2] these curious little creatures, inhabiting the islands of Mauritius and Madagascar, and the adjacent coast of Africa, have been ranked as a subdivision of the *Quadrumana* on account of their arboreal habits, their prehensile limbs, and some anatomical resemblances to the monkeys; but an examination of their *placenta* has convinced Milne-Edwards that they are quite as nearly allied to the *Carnivora* as to the *Quadrumana*, and that they should form a distinct *order* between and connecting the other two; and this conclusion, he says, is supported by a comparison of the brain, the limbs, the skull, and the teeth.

Now, if this be correct, and if we admit that in *some way* our existing species have been derived from other and preëxisting forms,

[1] This is fifty millimetres (a trifle over two inches); the full stop is placed *after* the place for the number of metres, the unit of the measure of length; a comma is placed after the millimetres, thousandths of a metre. The old fox weighed 2,918. (two thousand nine hundred and eighteen grams, the full stop coming after the number of grams, the unit of weight), or about 6½ pounds; she was rather thin; foxes are sometimes taken weighing 10 and 11 pounds, but usually about 9; the young weighed about 15 ounces each (avoirdupois); ,375. ,377. and ,417. grams respectively; their eyes were not fully opened; all their ears were injured either by frost or the bites of dogs, and their form is uncertain.

[2] "Annales des Sciences Naturelles," Fifth Series, vol. xv.

then it is not at all difficult to account for the resemblance of our little fox to a monkey, or of certain monkeys to dogs, upon the supposition that both groups of animals, the *Quadrumana* and the *Carnivora*, are divergent branches from a common stock, resembling the lemurs more than either of them.

But, aside from such speculations as to the reason for the differences above alluded to, their existence is undeniable; and it is surprising to find how very few are the figures and descriptions of *young* mammals; the last scientific letter written me by Prof. Agassiz (September 10, 1873) strongly urged the importance of including, within the embryology of domesticated animals, the changes which they undergo *after birth;* and he particularly requested that the dogs, and the *wild canidæ* as well, should serve as the starting-point. Enough has been said to show that these changes are very great in the fox, and that they may furnish suggestions at least, as to origin and natural relationships.

RENDU AND HIS EDITORS.

By JOHN TYNDALL.

"Some have blamed me, and some have praised me, for the part I have acted toward Rendu. In one distinguished, but not disinterested quarter, I am charged with prejudice and littleness of spirit, to which charge I make no reply. But let it be shown to me that I have wronged any man by false accusation, and Zaccheus was not more prompt than I shall be to make restitution."—("Mountaineering in 1861.")

TO review a book is an unusual occurrence with me: other duties putting in a prior and peremptory claim. Still I could not, when honored with a request to do so, decline making the few observations which the brief time allowed me renders possible, on a volume just published under the joint auspices of Prof. George Forbes, Prof. P. G. Tait, Prof. John Ruskin, and Mr. Alfred Wills.

Science and Art here unite in denouncing a small book of mine entitled the "Forms of Water," to which reference has been already made in these pages.[1] Putting certain of its sentences into what they call "straightforward English," they draw the inference that my object in writing it was, in a more or less mean and underhand way, to "dim the lustre" of the late Principal Forbes's glacier-discoveries, to filch his laurels, and to dishonor his memory by fixing on him the charge of plagiarism." Other friends of the late Principal cannot, however, discover in the book any wickedness of this kind, while *no* friend of mine can discover it.

In the preface to the fourth edition of the "Forms of Water," published a few days ago, I state its origin, object, and spirit, and my atti-

[1] Vol. xxii., p. 484.

tude toward such criticisms as had then appeared, to be as follows: "I had been frequently invited to write on Glaciers in encyclopædias, journals, and magazines, but had always declined to do so. I had also abstained from making them the subject of a course of lectures at the Royal Institution, wishing to take no advantage of my position there, and indeed to avoid writing a line or uttering a sentence on the subject for which I could not be held personally responsible. In view of the discussions which the subject had provoked, I thought this the fairest course.

"But, in 1871, the time (I imagined) had come when, without risk of offense, I might tell our young people something about the labors of those who had unraveled for their instruction the various problems of the ice-world. My lamented friend and ever-helpful counselor, Dr. Bence Jones, thought the subject a good one, and accordingly it was chosen. Strong in my sympathy with youth, and remembering the damage done by defective exposition to my own young mind, I sought, to the best of my ability, to confer upon these lectures clearness, thoroughness, and life.

"I aimed, indeed, at nothing less than presenting to my youthful audience, in a concentrated but perfectly digestible form, every essential point embraced in the literature of the glaciers, and some things in addition, which, derived as they were from my own recent researches, no book previously published on this subject contained. But my theory of education agrees with that of Emerson, according to which instruction is only half the battle: what he calls *provocation* being the other half. By this he means that power of the teacher, through the force of his character and the vitality of his thought, to bring out all the latent strength of his pupil, and to invest with interest even the driest matters of detail. In the present instance, I was determined to shirk nothing essential, however dry; and, to keep my mind alive to the requirements of my pupil, I proposed a series of ideal ramblings, in which he should be always at my side. Oddly enough, though I was here dealing with what might be called the abstract idea of a boy, I realized his presence so fully as to entertain for him, before our excursions ended, an affection consciously warm and real.

"A German critic, whom I have no reason to regard as specially favorable to me or it, makes the following remark on the style of the book: 'This passion' (for the mountains) 'tempts him frequently to reveal more of his Alpine wanderings than is necessary for his demonstrations. The reader, however, will not find this a disagreeable interruption of the course of thought; for the book thereby gains wonderfully in vividness.' This, I would say, was the express aim of the breaks referred to. I desire to keep my companion fresh as well as instructed, and these interruptions were so many breathing-places where the intellectual tension was purposely relaxed and the mind of the pupil braced to fresh action.

"Of other criticisms, flattering and otherwise, I forbear to speak. As regards some of them, indeed, it would be a reproach to that manliness which I have sought to encourage in my pupil to return blow for blow. If the reader be acquainted with them, this will let him know how I regard them; and if he be not acquainted with them, I would recommend him to ignore them, and to form his own judgment of this book. No fair-minded person who reads it will dream that I, in writing it, had a thought of acting otherwise than justly and generously toward my predecessors, the last of whom,[1] to the grief of all who knew him, has recently passed away." I thus show how willing I was three weeks ago to let discussion cease.

How a great and good man regarded this book is shown by the following extract from a letter from the late Prof. Sedgwick, to whom I sent the first draft of the volume. I gather from the "Life and Letters" that he was a friend of Principal Forbes. The extraordinary freshness of his nature breaks through the concluding lines, which, save as an illustration of this, I should hardly have ventured to quote. There are others which I omit for obvious reasons:

"CAMBRIDGE, *January* 29, 1873.

"MY DEAR PROFESSOR: I write to thank you for the little book upon the glaciers of the Alps you had the kindness to send to me, and for the instruction and delight its perusal gave me. . . . It shows a power of putting the subject in the clear, bright colors of daylight before the reader's eyes, and making him feel as if he were your happy companion and fellow-laborer.

"Truly and gratefully yours, A. SEDGWICK."

This is the language of a philosopher who took my words as they stand, and did not think it necessary "to put that and that together," so as to convert my statements into "straightforward English."

The law of causality is now an *a priori* dictum of the human mind. There is no spontaneous generation of phenomena; and, like all other things, the book now under consideration had its antecedents. These are in great part to be found in a discussion which occurred twelve years ago regarding the scientific position of a noble but a suffering man. By his unaided genius, Dr. Robert Julius Mayer, of Heilbronn in Germany, reached the heart of a generalization, which the professional hierarchy of science in his day had failed to reach, and which in its later developments ranks as high as the principle of gravitation. For this great *Bahnbrecher* I sought recognition; but the recognition was by no means immediate, nor was my act applauded by all. Much the reverse. I was accused, not only of want of patriotism, but of "depreciation and suppression." I was charged with ignorance, and an "abuse of language." Every spark of originality was denied to Dr. Mayer. The calculation of the mechanical equivalent of heat, which I had ascribed to him, was claimed for M. Seguin, who, it was alleged, had, three years before Mayer, made the same calculation, and obtained

[1] Agassiz.

the same numerical result. These assertions were uttered with a confidence not surpassed by any thing contained in the volume just published by Mr. Macmillan. The sufficient reply to all this now is, that, since those days of strife, Dr. Mayer has received the highest rewards which the greatest scientific academies and societies in Europe could confer upon him; and that he now stands above detraction and debate, immovably fixed beside his illustrious experimental brother, Joule: a figure memorable to all time in the annals of science.

The gentle knight who in those days, with such conspicuous disaster to himself, took the field against me, is also my chief opponent now. He is the principal figure among the authors to whom I have referred, and I allude to these facts in order to bring him and his work into the causal series of contemporary phenomena, and to show cause for the warning that obstinacy of assertion on his part furnishes a by no means sufficient assurance that his assertions are objectively correct. Indeed, where we find these assertions associated with more than the usual want of sweetness and luminosity, the presumption arises that the judgment which proved entirely fallacious on a former occasion may at present, to say the least of it, be unsound.

The volume which calls forth these remarks is entitled "Theory of the Glaciers of Savoy," by M. le Chanoine Rendu; and the middle of the book is, I am happy to say, occupied by a translation of this remarkable essay—in itself a perfectly honorable and praiseworthy work. The volume opens with an introduction by Prof. George Forbes, son of the late Principal Forbes, which, measured by former discussions on this subject, is by no means immoderate in tone. Had this tone, indeed, been preserved throughout the discussion, these remarks of mine would never have been written. It is not in my nature to refuse sympathy to a son battling, as he imagines, for the honor of his father. But Prof. George Forbes has deliberately taken upon himself the responsibility of writings, samples of which shall be given further on, not with the view of maintaining his father's honor, but with the view of gratuitously sullying the honor of others. This, filial allegiance neither demands nor can excuse.

He prints some letters in his Introduction animadverting more or less upon me and my friends; but written at a time when the writers were very inperfectly acquainted with the subject on which they wrote. Dr. Whewell was from the first a warm supporter of Principal Forbes, and an equally warm opponent of Mr. William Hopkins; and, when my small labors on the glaciers came to be discussed, the preëxisting difference between these two distinguished men became intensified, in a high degree. It was Dr. Whewell who, in discussion with Mr. Hopkins, summed up my doings with the remark that I had simply taken Auguste Balmat to the summit of Mont Blanc and caused him to be frost-bitten.[1] It was he who in 1859 proposed Principal Forbes as a

[1] *Contemporary Review*, vol. xxii., p. 485.

candidate for the Copley medal,[1] which the Council of the Royal Society did not grant. He was angry at the time; but it pleases me to remember that subsequently in the Athenæum Club he renewed acquaintance with me, and gave me the benefit of his most agreeable and instructive conversation about glaciers.

The letter from Dr. Playfair can also be placed in a moment in its proper relation to other facts. A foot-note at page 195 of the first edition of "Heat as a Mode of Motion" runs thus: "Since the above was written, the 'Glaciers of the Alps' has been published, and soon after its appearance a 'Reply' to those portions of the work which referred to Rendu was extensively circulated by Principal Forbes. For more than two years I have abstained from answering my distinguished censor, not from inability to do so, but because I thought, and think, that within the limits of the case it is better to submit to misconception than to make science the arena of a purely personal controversy." Not for two years, but for ten years did I permit, for peace' sake, this misconception to continue; it refers to allegations as to omissions made against me by Principal Forbes, and disposed of at p. 498 *et seq.*, vol. xxii. of the *Contemporary Review*.

It will be seen at the place here referred to, that the strongest argument of Principal Forbes relates to a statement regarding *crevasses* made by Rendu; and Mr. George Forbes now contends for the correctness of his father's views. I can assure him, in all good temper and good faith, that he is hopelessly wrong; that his father entirely misapprehended Rendu; and that the argument founded on this misapprehension, though apparently so incontrovertible, and so damaging to me, is in reality not worth the paper on which it stands. During the lifetime of Principal Forbes I never once disturbed him in the enjoyment of his delusive triumph, and my life also would have passed without any attempt at refutation had not his biographers flaunted the argument again in my face, and compelled me to reduce it to the condition in which it appears in my last article. Had I, as alleged, been disposed to wound Principal Forbes, I should not have acted thus.

I had stated in the "Glaciers of the Alps," and in this Review, that some very important measurements made by Agassiz in 1841 and 1842, by which the differential motion of a glacier was demonstrated, had been ignored in all the writings of Principal Forbes. Though so much occupied with the subject, I was in absolute ignorance of the existence of these measures myself until my attention was drawn to them by Sir Charles Wheatstone, immediately before the publication of the "Glaciers of the Alps." Prof. George Forbes now charges me with forgetfulness of the fact that it was his father who suggested to M. Agassiz the measurements he made; meaning thereby, I suppose, to intimate that his father was not called upon to recognize measurements which were the result of his own instruction.

[1] On this subject, *see* Prof. Huxley's masterly letter in *Nature*, May 22, 1873.

I would, however, ask Mr. Forbes to consider whether I, while endeavoring to hold the balance fairly between contending claims, should have been justified in accepting his father's assertion and ignoring the diametrically opposite assertion of Agassiz? On this point I would direct his attention to two sources of information; the one probably known to him, the other unknown, and which the desire not to inflame this controversy has prevented me from publishing hitherto.

In the first place, I will make a brief extract from a very rare *brochure* published by Agassiz, in evident affliction of mind, in 1842. In that pamphlet he addresses thus his guest of the previous autumn:

"What eloquence have I not wasted in order to cause you to accept such and such a conclusion; what lengthened excursions, extending over days, have I not made to convince you of such and such a fact? And what advantage did I derive from nearly a month of these labors? This solely. On every new subject of discussion you favored me with the profound reflections: it is very curious; it is very extraordinary; it is most remarkable; it is capable of various interpretations; various causes might have produced these effects! Never a word on the true basis of the question. And, notwithstanding this, I told you all, showed you all, even things regarding which I had published nothing."

I was in duty bound to give due weight to this side of the question; and in 1859, prior to the publication of the "Glaciers of the Alps," I wrote to M. Agassiz, inquiring whether he still maintained the position here assumed; which, it will be seen, not only touches, but *is*, the very point brought forward by Prof. George Forbes. I will give the pith of his reply, which, as just intimated, has lain beside me unpublished for fifteen years. After sketching the "incredible difficulties" of his early glacier campaigns, his uncertainty regarding the measurement of the motion of bowlders, his failure on the Aar, and Escher's failure on the Aletsch, to determine the motion of a series of stakes fixed in 1840, because, through ignorance of the amount of ablation, they did not sink them deep enough in the ice, Agassiz answers me thus:

"It was not until after my second visit to the Aar in the winter of 1840–'41 that I felt myself prepared for a systematic experimental investigation of the glacier; and I then went up, not with the hope of solving all the problems in one year, but with the view of laying the basis of a solution. The fact that I staked a series of poles across the whole width of the glacier, to a depth which left them standing to the following year, and that I then went up with an experienced engineer to make a minute map of the entire surface of the glacier, which was executed, will show that I had laid my plans for a successful survey of glacier phenomena before Prof. Forbes had, for the first time, set his foot upon the glaciers with a view to studying them.

"When I invited him to spend some time with me upon the glacier in 1841, I hoped to receive some valuable hints for my investigations from a physicist of so high a standing as his. But he never suggested any thing to me, while I showed him every thing I had been doing, explained all my difficulties, and the

devices with which I proposed to overcome them. That Prof. Forbes reached the Mer de Glace in 1842, a few weeks before I went up the Glacier of the Aar, only gave him the opportunity of making a few days' observations at a time when I had already gained an annual average. *That Prof. Forbes knew in* 1841 *of my intention to make this experiment I can affirm the more positively as he saw the iron bars with which I intended to bore the holes, and which had been carried up the glacier before he reached the Grimsel.* That I was going to use instruments of precision in these measurements he must have understood, since I repeatedly mentioned my purpose of making a trigonometrical survey of the glacier the following year. Whether I at any time mentioned the theodolite I cannot remember now. But I am sure that he never suggested any thing to me.

"Allow me one more remark. Everybody knows that I am a naturalist, and not a physicist. My interest in the glaciers arose from a desire to learn something of the mammoth of Siberia, after I had become convinced by Charpentier that the glaciers of Switzerland were much more extensive in earlier times than now. It struck me that there might be some connection between the burial of these gigantic mammalia in the arctic regions and the wider range of glaciers in Switzerland; I am one of those who believe, as you expressed it in your short and characteristic speech at Geneva, that 'Nature is One,' and so I was led to study the accumulations of ice without the necessary preparation. This you cannot fail to perceive in reading the accounts of my successive attempts, and for this, I hope, some allowance will hereafter be made."

This account fairly tallies with the statement of Prof. Forbes in his "Travels," quoted in his "Life" (p. 503):

"Far from being ready to admit, as my sanguine companions wished me to do in 1841, that the theory of glaciers was complete, and the cause of their motion certain, after patiently hearing all that they had to say, and reserving my opinion, I drew the conclusion that no theory which I had then heard of could account for the few facts admitted on all hands, and that the very structure and motions of glaciers remained still to be deduced from observation."

Incomparably greater than Forbes in his own field, the want of physical knowledge, to which Agassiz refers at the conclusion of the foregoing letter, rendered him, on this particular ground, a mere child in comparison with his guest. Still, if the statement which I have italicised in Agassiz's letter express a fact, then, while entertaining no doubt that Prof. Forbes justified his conduct to his own mind, I leave it to others to judge whether it would not be an evil day for the frankness of scientific intercourse if such conduct should become general.

It is difficult at the present day and hour to convey an idea of the stir caused by the communication of our joint paper to the Royal Society by Mr. Huxley and myself; but many of us remember the violent discharge of letters which followed that event. Had I in those days a tendency to be puffed up, the circumstances were certainly such as might exalt my self-importance. But, as a matter of fact, the whole business was exceedingly saddening to me. For two years I endeavored, while not flinching from what I held to be the duty of a

scientific man, to turn away by soft answers the wrath excited against me. I failed to do so. The tone of depreciation indulged in was typified by the remark of Dr. Whewell above quoted, and threats of punishment were everywhere rumored. I refer to these almost forgotten occurrences, which need never have been revived, to show how natural it would have been for me to assume in the "Glaciers of the Alps" a more decidedly controversial tone than that actually assumed in it.

Many of the claims then made for Principal Forbes were perfectly inconsistent with the facts known to me. Sir Charles Wheatstone had pointed out those measurements to which Agassiz refers as having been begun under Prof. Forbes's eyes, and which were more than ignored. I had also read Rendu's Essay, and found there matters absolutely unknown to the supporters of Principal Forbes, and directly at variance with statements current in high quarters. I also noticed, or thought I noticed, a tendency, glanced at in my former article, to regard the self-same data as important or unimportant according as they were employed by Forbes or Rendu.

Let me illustrate my meaning here. One of the strongest passages cited by Principal Forbes to show that he had recognized the merits of Rendu, which I never denied, but expressly admitted, is this ("Travels," page 382): "The idea of comparing a glacier to a river is any thing but new, and I would not be supposed to claim that comparison or analogy as an original one. Something very like a conception of fluid motion seems to have been in the minds of several writers, although I was not aware of it at the time that I made my theory. In particular, M. Rendu, whose mechanical views are in many respects more precise than those of his predecessors or contemporaries, speaks of 'glaciers d'Écoulement' as distinct from 'glaciers Reservoirs,' and in the quotation at the head of this chapter he contemplates the *possibility* of the mutual pressures of the parts overcoming the rigidity. He is the only writer of the glacier school who has insisted on the plasticity of the ice, shown by moulding itself to the endlessly varying form and section of its bed; and he is also opposed to his leading contemporaries in his conjecture that the centre of the ice-stream would be found to move fastest. But," and here comes one of those qualifying phrases to which I have already referred,[1]—"M. Rendu has the candor not to treat his ingenious speculations as leading to any certain result, not being founded on experiments worthy of confidence."

I will ask permission to go one step farther. At the British Association Meeting at York, that able mathematician and high-minded gentleman, Mr. W. Hopkins, got into a sharp discussion with Prof. Forbes regarding the viscous theory, and he, subsequently, wrote upon the subject in the *Philosophical Magazine*. In the same journal Forbes published a reply; one of the strongest points of which, if

[1] *Contemporary Review*, vol. xxii., p. 507.

not the very strongest point, is the following. Speaking of the principle of plasticity, Prof. Forbes writes:

"Perhaps the following illustration will appear to the impartial reader almost a demonstration of this principle. . . . There is a glacier basin in the range of Mont Blanc called the Glacier du Talèfre. Its outline is correctly represented in the next figure, as well as the relative dimensions of the mouth or outlet by which it pours forth the mass of ice which it is annually unable to contain in its circuit. The breadth of the outlet is about seven hundred yards, while the greater diameter of the basin which it discharges is more than forty-two hundred yards, or at least six times greater. Can it for one moment be imagined that any degree of *lubrication* of the bed of this cake of ice could drag it through the strait in question, even if its adhesion to the soil were absolutely nothing? The thing is impossible; it speaks for itself."[1]

The observation here referred to as so convincing is precisely of that class upon which Rendu founded his theory; and there cannot be a reasonable doubt that the very fact here brought forward more or less influenced him. Still, while in the hands of Prof. Forbes it has the value here set forth, in those of Rendu the "ingenious speculations" founded upon it are not "worthy of confidence."

It is not, and never was, my design to charge Principal Forbes with conscious wrong; but, at the time here referred to, I believed him to be animated by a love of public recognition so eager, and an estimate of the value of his own work so exalted, as to render it difficult for him to behave in a generous way toward those whose labors trenched upon his own. I regarded his treatment of Agassiz as harsh, if not merciless. Considering all this, I do not think that the "Glaciers of the Alps," written in the midst of such contentions as I have indicated, can be justly deemed intemperate in tone. Its logic is sometimes stern;[2] but its statements are irrefutable. To its chapters, from page 269 onward, I would refer the reader for an answer to a good deal of the irrelevant bluster associated with this question.

I am blamed for saying that, if Rendu had added to his other qualifications those of a land-surveyor, he would now be deemed the "Prince of Glacialists." Can this be for a moment doubted? When we find him announcing, with a fullness and precision never surpassed, and not attained even by Prof. Forbes himself until years after the publication of his "Travels," the character of glacier-motion; when we find him laboriously trying to determine it by observations of blocks at the edge and toward the middle of the glacier—is it to be imagined that, if he knew the use of the theodolite, he would not have employed that instrument? And is the absence of this surveyor's knowledge a just reason for dismissing his labors in the fol-

[1] *Philosophical Magazine*, vol. xxvi., pp. 414, 415.

[2] What a courteous demeanor might have done to modify this, I cannot now say, but I know that, after the death of Principal Forbes, no reference of mine to his work or memory lacked appreciation or kindness.

lowing fashion in the "Life and Letters of Principal Forbes?" After having referred to the Dilatation and Gravitation Theories, and to an observation of Playfair's, the writer proceeds: "We are not aware that any thing of particular importance beyond this was known, in the sense of having been *observed*, not merely *seen*, till Forbes took up the subject, with the exception of Rendu's acute remark, which appears to have been previously made by Captain Basil Hall and others, that a glacier seems to flow in its channel like a sluggish stream." This is as inadequate as it is unjust; and I would also, once for all, respectfully protest against the following language as describing with even approximate fairness the relation of Rendu to this question: "One of the few men who seems in any point of consequence to have had even one clear and accurate idea on the subject before Forbes is Mgr. Rendu, late Bishop of Annécy, but this was so mixed up with error that it does not appear likely that in his hands it could have ever led to any thing definite; for Rendu holds and enunciates, sometimes in the same sentence, facts and errors utterly incompatible with them."[1] This is the spirit of depreciation which has introduced bitterness into these discussions, and which will not be shared by any just or generous mind.

Prof. Tait has prepared himself for his portion of the book here under review by some researches which prove that a "grudge on my part against Prof. Forbes was in full bud as early as 1854." He moreover credits me with "extremely great skill in choosing precisely such forms of language as were calculated to produce the most exquisite torture in the mind of a scrupulously upright and high-souled man." That I should exhibit skill in any thing is to me astonishing. What he here says, coupled with what he had said before regarding my ignorance, is a mere feeble copy of his description of Mr. Lowe—a man "compounded in about equal proportions of fiend and fool;" and such repetition is unworthy of the versatile genius of Prof. Tait. Speaking seriously, we have, in both cases, the mere wildness of uncontrolled anger. I had no more grudge against Prof. Forbes in 1854 than against Prof. Faraday, and friendly letters passed between Forbes and myself long subsequent to this date. In fact, if I had any grudge, it was rather against Agassiz than against Forbes, for in those days I was impatient with Agassiz's physics, but otherwise ill acquainted with the merits of the case between them. Might I commend to my critic the following deliverance of his distinguished countryman Prof. Bain? "Our emotions of *anger*, like fear, are manifestations superinduced upon mere pain. Revenge, antipathy, hatred, party spirit, are so many forms of the irascible feeling, and are antagonistic in a conspicuous degree to the ascertaining of truth. Calumny, the expression of anger, connotes falsehood."

I willingly accept Prof. Tait's grammatical correction as regards

[1] Prof. Tait in "Life and Letters of Forbes," pp. 494, 498.

the introduction of two articles, and the substitution of the word "mutual" for "natural" in the statement of the viscous theory. Such mistakes readily escape me in the reading of proofs with the meaning of which I am very familiar; and some similar errors in my other works, discovered mainly by my own pupils, await correction in subsequent editions. In the "Glaciers of the Alps," my critic will find "mutual" all right, and one of the indefinite articles supplied. But the shifting of the vowel to a consonant was overlooked, and the second article was therefore omitted.

From the level of the irascible, Prof. Tait on one occasion rises to that of exultation. "While we write," he exclaims, "another actor has appeared on the scene—and with tremendous effect. The terrible words of Mr. Ruskin (Fors Clavigera, Letter xxxiv.), with regard to Dr. Tyndall and his 'Forms of Water,' will reach myriads of intelligent readers besides those who could otherwise be expected to interest themselves in a question involving scientific issues. Mr. Ruskin's admirable command of language, his clearness, impartiality, acuteness, and his exemplary firmness in declaring truth, and doing justice, leave nothing to be desired."

These are strong words. What is their value? Let a very able sample of Mr. Tait's countrymen reply. "He" (Prof. Tait), says the *Scotsman* of April 24th, "may be occasionally shy in his substantives, but he has no timidity in his adjectives. 'Contemptible,' 'unutterably contemptible,' 'miserable,' 'disgusting,' 'shabby,' 'pernicious,' 'pestilent,' 'hideous,' are among the projectiles, more natural perhaps than philosophical, which the Professor of Natural Philosophy distributes round him." But whence, it may be asked, this exorbitant jubilation? What on earth can the opinion of Mr. Ruskin have to do with the solution of a question which has stood in the fierce light of scientific discussion for fourteen years? Is it to be imagined that he has found something which has escaped Helmholtz or Sedgwick? Surely, if Prof. Tait will only give his clouds of anger time to disappear, he will see the absurdity of introducing such loose rhetoric among grave students of science.

Further on we have Principal Forbes's pure and disinterested love of knowledge for its own sake, contrasted with that of others who seek it for the sake of notoriety. Let me examine this notion in the light of a crucial instance.

In walking up the glacier of the Aar with Agassiz, Prof. Forbes observed blue veins running through the ice. Agassiz had noticed the grooves answering to them on the surface, but he had not studied them, and in all likelihood he blundered in his conversation about them with his acute and physically-cultured guest. They followed these veins subsequently together for several days, and, after the departure of Forbes, Agassiz traced them to a depth of a hundred and twenty feet. Humboldt, I am informed, had been instrumental in getting

him pecuniary aid for his researches, and to Humboldt, after the glacier campaign of 1841 had ended, he addressed a *private* note, mentioning among other things his having seen the veins. I make no attempt at excusing his omission of the name of Forbes from this note; but, taking every thing into account, the sin of omission does not seem very heinous. Its effect upon Prof. Forbes shall be described by himself.

"I reached home," he says, "in the month of October, 1841, and soon commenced the historical review of the glacier question which I had projected. While I was thus engaged, the 'Comptes Rendus' of the Academy of Sciences in Paris for the 18th of October reached me. In it I found a letter from M. Agassiz to Baron Humboldt, containing the following passage with reference to the observations made upon the glacier of the Aar:

"'Le fait le plus nouveau que j'ai remarqué, c'est la présence dans la masse de la glace des rubans verticaux de glace bleue, alternant avec des bands de glace blanche d'un quart de ligne à plusieurs pouces de large, s'étendant sur toute la longueur du glacier et penetrant à une profondeur du moins 120 pieds puisque j'ai observé encore ce phénomène au fond du trou de sonde.'

"On reading this letter," says Principal Forbes, "from which even all mention of my presence on the Aar is excluded, my first impression was of surprise and pain. That I could not suffer so direct a plagiarism to remain unchallenged never appeared to me to admit of a doubt; *le fait le plus nouveau que* J'AI *remarqué* was an assertion as articulate as it was unfounded."

For nearly a month Prof. Forbes had shared the shelter of Agassiz's roof, and wandered with him among scenes of unsurpassed grandeur. He had found in his host "noble ardor, generous friendship, unvarying good temper, and true hospitality." It is upon the man thus described by himself that Prof. Forbes turns in this fierce way, for the mere omission of his name. It grieves me to say a word which could be interpreted as severe to a dead man; but the comparisons drawn by his panegyrist compel me to state that, among the eminent men whom it is my privilege to call my friends, there is not one to whom such an explosion of resentment for so purely personal—I had almost said paltry—a cause would be even approximately possible. I charge him with nothing consciously unfair; but from a man so hot in the assertion of his "claims," so sensitive to public recognition, and so free in the use of hard words, these interminable discussions run as naturally as rivers from their water-shed.

With more time at my disposal I should probably enter more fully into these matters; but this and my former article, taken in conjunction with the "Forms of Water," in which, even to the ignoring of myself, I desire to do justice both to Agassiz and Forbes, and the pages referred to in the "Glaciers of the Alps," will have so far cleared a dusty atmosphere as to enable any really earnest reader to see the bearings of this question. It now only rests with me to give some samples of those "terrible" and "tremendous" words to which Prof. Tait has referred, and which Prof. George Forbes has thought fit to

make a portion of his volume. Forty years ago, Mr. Ruskin first saw the Alps from Schaffhausen.

"Only one great step," he says, "in the knowledge of glaciers has been made in all that period; and it seems the principal object of Prof. Tyndall's book to conceal its having been taken, that he and his friends may get the credit, some day, of having taken it themselves. . . . At the end of the last book of his he" (Prof. Tyndall) "denies, as far as he dares, the essential points of Forbes's discovery. . . . The readers of 'Fors' may imagine they have nothing to do with personal questions of this kind, but they have no conception of the degree in which general science is corrupted and retarded by those jealousies of the schools; nor how important it is to the cause of all true education that the criminal indulgence of them should be chastised. Criminal is a strong word, but an entirely just one. I am not likely to overrate the abilities of Prof. Tyndall; but he had at least intelligence enough to know that his dispute of the statements of Forbes by quibbling on the word viscous was as uncandid as it was unscholarly; and it retarded the advance of glacier science for at least ten years. . . . And the absurdity, as well as the iniquity, of the professor's willful avoidance of this gist of the whole debate is consummated in this last book, in which, though its title is the 'Forms of Water,' he actually never traces the transformation of snow into glacier-ice at all."

If these "terrible" words be *true* words, why was it left to an amateur to utter them? Why were they not uttered years ago by Prof. Tait himself? To these and other observations of Mr. Ruskin I offer no reply; nor should I have ever given them the slightest regard or attention were it not for the use which a scientific man has stooped to make of them.

"Fors Clavigera" has but a scanty circulation—how, then, were the "myriad intelligent readers" of Prof. Tait obtained? Simply by circulating "Fors" in Scotland, and republishing Mr. Ruskin's article in the Scotch newspapers. Prof. Tait, moreover, was for some years attached to Queen's College, Belfast, and I am to have the honor of presiding at the meeting of the British Association to be held next August in that city. Accordingly, the article in "Fors" has been republished in the Belfast journals also. The *Northern Whig* and the *Belfast Newsletter* have duly reached me with Mr. Ruskin's article conspicuously marked. These are some of the amenities of Prof. Tait: others are at hand, but I refuse to notice them. The spirit which prompts them may, after all, be but a local distortion of that noble force of heart which answered the "Cameron's gathering" at Waterloo; carried the Black Watch to Coomassie; and which has furnished Scotland with the materials of an immortal history. Still, rudeness is not independence, bluster is not strength, nor is coarseness courage. We have won the human understanding from the barbarism of the past; but we have won along with it the dignity, courtesy, and truth of civilized life. And the man who on the platform or in the press does violence to this ethical side of human nature discharges but an imperfect duty to the public, whatever the qualities of his understanding may be.—*Contemporary Review.*

THE CHAIN OF SPECIES.

By Hon. LAWRENCE JOHNSON.

PART II.

WHEN Wolf, Goethe, Oken, and Geoffroy St.-Hilaire began to tell us that the method of the creation of living creatures is an evolution, it was far from satisfactory. To comprehend the proposition in the first place was exceedingly difficult. It was almost incomprehensible, indeed, to minds tutored in the anthropomorphic notions of spasmodic and arbitrary special efforts on the part of some Demiurgus. Educated to see in Nature what were called evidences of design, meaning plan and purpose according to our finite ideas of design, we could not rise to the conception of the continuous action of universal law; and every thing not easily construed by our preconceived teleology was settled by the convenient doctrines of miracles and cataclysms. In another way, also, the world was not prepared for the proposition; for, in the second place, the proofs were hidden away in the still undiscovered facts of homology. The science of morphology was yet to be created. Not yet was it known that Bryant's solemn verses—

> "All that tread
> The globe are but a handful to the tribes
> That slumber in its bosom"—

are as applicable to the genera and species of all living creatures as to the individuals of the human race; that the organic forms now extant are in simplest truth insignificant, both as to numbers and varieties, when compared with those which have preceded them and which have perished forever.

No wonder, then, that the new-fledged doctrine of evolution soon went out of fashion when even the great disciples of the great leaders just mentioned, Lamarck and the elder Darwin, had no better explanation to offer than the hypothesis of transmutation. Yet it ought not to be forgotten that their principal opponents were not devout professors of religion and theology, to the really qualified of whom, it must have been indifferent; but Voltaire, Frederick II., Cuvier, and Agassiz, men whom no one ever suspected of any profound knowledge of theology, or of special reverence for its deductions.

But now the mists are clearing away, just as, according to the logic of things, we should expect. For there is evolution in human thought and comprehension, as in all things else. Yet the how—the question of the method—the process of the development of life—still confronts us; and the recent labors of Charles Darwin, Wallace, Voght, Haeckel, Cope, and others, have taught us that the answer is

not to be jumped at by mere speculation, nor by hasty inference from the sparse and ill-digested facts of natural history now in our possession. The full solution of the mystery still lies in the future, and is to be reached only after the collection and comparison of a mass of data overwhelming to contemplate. In the mean time, confusion of ideas and differences about words characterize all our controversies. How men will misunderstand one another!

> "We have an idea, make a word,
> Too false t' unite us, or control;
> And for the word itself we fight
> In bitterness of soul."—WORDSWORTH.

It is usual to state that there are two theories of the origin of species, of the production of organic forms, namely, the theory of special creations, and the theory of natural selection. But the statement stands in need of criticism. The supposition of a special genesis, whether by some assumed *ab extra* influence, in other words, miraculous interference, or by some influence working *ab intra*, is a virtual begging of the question, a virtual admission that we never can follow the chain of causation. And this, because at some stage of the process the battle is to be stopped; at some step of the argument our mouths are to be shut, if not with a miracle after the manner of the Sunday-school teachers, which has at least the merit of piety about it, then with the more formidable obstruction of an *inexplicable* fact or property. And we are actually told, by one of this turn of thinking, that "to bother ourselves about these inexplicable facts is as irrational as to discuss the politics of the moon."

But, leaving special genesis aside, let us consider a little more closely the doctrine of natural selection. This, in fact, is not a theory of the origin—of the genesis of species. As M. Quatrefages has remarked, it is not a theory at all, for it explains nothing, accounts for nothing, and is not therefore truly an hypothesis in philosophy. Natural selection is not a cause, but the discussion of it draws attention to the chain of causes at the bottom of which we must look for the solution of our problem. As we all know, it is a notion taken from the selection exercised by the hand of man in the rearing of domestic plants and animals. Man, by the conscious or unconscious selection of that which best suited his wants or caprices, has educed and displayed many varieties of living creatures; and in like manner it is suggested that Nature, by holding on to the fittest in the struggle for life, has herself made selection of the innumerable forms we see. In a general way, this principle has always been recognized; and in past ages it has been always remarked that the varieties discovered are well adapted to exist, and that, if they were not so adapted, they would perish. But we have yet to see that these variations are always the fittest, or that the fittest comparatively always survive.

But, indeed, so far as Mr. Darwin puts forth a theory at all, it is not that natural selection is the cause of species; but that slight accidental variations occur from some unknown or inexplicable cause; and that by natural selection the fittest of these will survive.

There is not so much difference after all between the two so-called theories as it is common to believe; the inexplicable accident brings them together at last. It is only the using of different words for the same notion. Variation, by slight accidental degrees, is quite as unphilosophical as the production of species, by decided *saltus* or springs, from some innate miraculous cause. Suppose, then, we drop the question of the origin of species and the cause of variation, and try to observe and understand the different stages of the growth and evolution of such living creatures as the earth is filled with, whether fittest or unfittest: would not this be much more consistent with the vocation of science? In itself it will be a delight, whether it solves any thing or not.

Assuming matter and its law or properties—and remember, again, that without them it would not be matter—how, and by what steps, and stages, and degrees, has it put on the myriad forms of life?

We will not enter into those deeper speculations of philosophy which range every thing in unity or duality—which divide Nature into matter and force—or look upon the cosmos as one substance under two aspects, static and dynamic; and regard matter, in mathematical language, as composed of points in space and time; or, using purer ontological phrases, as centres of *force* or *motion* under the cosmical relations of time and space. Nor is it necessary to draw comparisons between these conceptions. They are but doctrines of method, and for certain purposes one may use either. Neither is this the place to dwell upon the forces, their correlation, and their unity; nor upon the principles of physics as a science. All this will be assumed as generally understood.

Matter we have; now life!

Suppose every thing prepared—a home, the earth, fitted to receive the invited guest; whence the mysterious power, vitality? The altar is prepared, the wood cleaved, and the sacrifice laid thereon: how was the fire from heaven invoked?

Recollect this maxim of even the old scholastic philosophy: that, having matter and form—that is, Nature and its laws—we are not to search outside of these, for we need no other factors to account for all the metamorphoses this basement matter may assume.

The first appearance of organic life—the stealing of this first fire from heaven—this is the easiest step in the whole process; easiest, naturally, because nearest to the inorganic kingdom, which is so much less complicated than the organic; easiest, because, as we advance, the factors which enter into the calculation and bear upon the result become so numerous and obscure that we never can know when we

have discovered the half of them; much less their interminable combinations. And yet, as to organic life in general, is it not confessed that, if we could only account for the existence of the cell, of that first morsel of colloid matter, we should have the key to all its mysteries?

Very well. What is a cell? Or, expressed in other words, what is that drop—that particle of matter, called now by that same old fashion of supplying phrases when ideas fail—protoplasm? What is protoplasm?

For aught we know, there may be monads or gemmules of organic creatures, as conjectured by Mr. Spencer and Mr. Darwin, there may be a peculiar substance endowed with life as a property, as conjectured by Mr. Huxley, there may be these atoms of organic life—the bases of organizations; and organized creatures may be definite arrangements of these, for aught we know. But really, except as a provisional theory, used, as we see it in the notion of Pangenesis put forth by the great naturalist, merely to aid in rising to other conceptions, there is very little need for such a supposition. Especially is it to be used guardedly. For, while put forth expressly in analogy to the atomic theory in chemistry, which is an aid to grasp the law of definite proportions, it is to be feared that many will so lean upon the crutch, they may never learn to walk. We know that in chemistry this is true; that many possessed of feeble powers of abstraction rest in the doctrine of atoms as the final fact; as in religion feeble minds stop at the forms and images used, and fail to comprehend the Deity taught and concealed thereby.

Rightly understood, the doctrines of Protoplasm, of Gemmules, *et id omne genus*, if they aid little, can do little harm. For, to the physiologist, there remains the great fact that *organization is life*. In, through, and by means of organization, or, if you prefer it, an organism, is matter endowed with life. So far as physiology, and therefore natural science and physics, is concerned in this matter, life does not exist without organization. Now, then, what is the first, the simplest form of organization—the primordial type of organic creatures? It is a cell. For, notice what is really meant by an organism—an organized creature. It is a creature that has functions dependent upon organs or parts. There is, then, in the very simplest organism already a manifestation of Von Baer's great law in biology—*differentiation*. Without differentiation there is no organization, and without organization, again, no life.

It is impossible to stop here to dwell upon the organization of a cell, and the proofs of it in unicellular creatures. This has been more fully treated of in some of my earlier productions. Still, a glance at this question—how? whence?—was promised.

See, then, this drop of colloid matter—this protoplasm—this cell. It can scarcely be called protoplasm until there is organization; and, if

so, then it is what the older anatomists called a cell. Can there be colloid matter without organization? Both chemistry and physiology answer in the affirmative. It may and does so exist in abundance. But it yet remains to be shown that the substance itself, *and all the other necessary external circumstances*, can meet without producing or exhibiting *life*. Not that our experiments have ever shown a single instance of the fact. But it has never in the failures been shown that every necessary concurrent circumstance was also applied. Far have every one of the experiments been from the least pretense to a perfect repetition of the exact circumstances which in the beginning did actually witness the genesis of the germs of life. Now that we have these germs we think it easier to understand their successive reproduction than their primal genesis. How far this is from the fact we have already noted.

When we have a morsel, a drop of nitrogenized colloid matter, we can easily comprehend how the attacks of oxygen will cause the evolution of those forces which again will cause a difference of functions in different parts; which, again, by this very differentiation become organs. Without a differentiation there would be no relation of the parts; no polarity; no motion; no circulation; no duplication; no increase—the best evidence of the presence of organic life. In our most ordinary notion of a cell there is all of this; and this motion, this polarity, this circulation, can be caused by oxygen alone, attacking a suitable compound. A circulation, which is but a repetition of rhythmical motion, once set up, organization is complete. Endow this organization with continuity, or the power of repeating itself, which the rhythmical circulation and polarity are capable of doing; endow it with the power of inspiring other colloid and crystalloid atoms with like vibrations, attracting them into its own mass, and then ejecting them again, arranged in form like to the original cell, which it will continue to do from habit, and you have living creatures.

Comparatively simple as this is, we are not so much concerned at present with the origin of life as with its metamorphoses. Having life in the shape of cells, and the first must be hypothetical, how does it advance? This is biological science.

The advance of life is also simple. It progresses by characteristics which must distinguish all organization, whether of organic or of inorganic elements—cosmical, chemical, or social. It is by aggregation, as Mr. Spencer has it—by a compounding. By compounding, and by differentiation; these are the two great laws.

The primordial cell, by holding on to the new broods of cells as they seek to escape from the parent hive—by retaining them and giving them a new division of labor for the common family—compounds and increases the energy of the common organism.

Every living creature, as we now know these creatures, is a compound. Simplicity is nowhere. Even the simplest the microscope can

show is probably already a compound of many removes from the beginning.

The law of compounding is not at all mysterious. If the first force of reproduction, the genesis of individuals, exhibits itself in the form of an evolution—a budding forth, a repetition of the form and structure of the parent cell—the law of compounding first presents itself as an *arrestation* of the law of gemmation. The old cell fails in force to throw off the new one; or, by another law, equally in force, adhesion takes place between the contiguous surfaces of the old and the new, and the extrusion to complete independence cannot be effected. This is the simple rule extending up through all the shining ranks and files of life. In the higher forms this law presents itself in the form of involution; but in lower creatures it is but an adhesion—an anchylosis. In all it is a *failure* of a perfect evolution—a failure perfectly to develop and reproduce a separate cell.

Now that we have the laws, let us see if we comprehend their application in Nature's workings. Really we might go to mathematics, and take from geometry, not only illustrations, but the very definitions of biology. Geometry, first and simplest of the sciences, begins its definitions with a point; from a point it proceeds to a line; from a line to a surface; from a surface to a solid. In biology, beginning with a cell, which is the physiological point or unit; the next development is to an axis, a line of cells, the type of all baculate structures. This baculus revolved upon itself, phyllate structure—a biological surface, the type of all organisms having one depth of cells. The next step is to the biological solid. This is made by an involution, a folding down of the surface upon itself, constituting a creature of two laminæ—two tiers of cells.

Passing on to another class, typically displayed for instance in hepaticæ, we find that another involution has taken place. This time the phyllum of two tiers of cells is folded upon itself, constituting one normally of four layers. Here first occur those curious openings into the centre of the structure known as stomata, rendered necessary, of course, from the fact that two of the strata are internal, and but for these contrivances would be cut off from that direct contact with atmospheric air which is necessary to the life of external living creatures. The next and the last evolution which takes place in the ascending development of plants is the folding upon itself of this leaf of four thicknesses of cells, so as to make a sheet consisting essentially of eight thicknesses of cells—the type of all the so-called higher plants. In this respect exogens and endogens do not differ; their only real difference being the atrophy and suppression of one cotyledon of the former to constitute the latter. In exogens there may be, in addition to these, various subordinate adhesions, but no further involutions of the whole creature. These may be called topical, as affecting only portions of the compound structure; and among endogens, from the

rolling up of the single phyllate cotyledon, these adhesions must be innumerable. Otherwise there would be no stems to plants of this class. A careful analysis will always enable us to trace the original layers, and, wherever reduced to a simple leaf, to find the law invariable.

It is manifest that all these creatures live externally. The leaf is the type of all; and every metamorphosis is some modification of a leaf. Even creatures of a single cell may be regarded as diminutive leaves; and all leaves are compounds of simple cells. The point is, the true manner of organization or of life. The grand peculiarity of all of them is that the great disturber—life-destroyer and life-giver, atmospheric oxygen—must come in direct contact with each and every cell. Organisms living in this way are called plants—a term which has no scientific meaning or value, since it indicates no relation to other creatures. All other living creatures constitute but one other grand kingdom; animals, another unscientific term. Unscientific as the terms are, it is generally supposed that we know pretty well to what they apply. We understand these are the first two branches from the main root of organic life, springing from the same original germ, and expanding into two great trees, never uniting nor mingling their boughs any more. It is easy to see the correlation of these two; the true distinction between them.

The so-called plant never loses the type or plan of the original leaf, of the primitive cell. It always remains phyllate, and living, as it were, cell by cell, in external relations to the air and the sources of nutrition. The so-called animal is more complicated. It differentiates completely the points, or spots, or organs of aëration and of nutrition; devotes one part of the organism to nutrition, and another to oxygenation. This is not all. Thus far probably all cells agree. But in animals the organs and functions of nutrition, at least, are in some fold of the tegument or sarcode, so that they store away their food in a special receptacle, and carry it about. This is as perfectly true of the most elementary amœba as of the elephant. This view of the ground of classification has been rejected by naturalists—by Dr. Carpenter among others; but this was done years ago, inconsiderately, and without the aid of recent advances in biology.

The amœba, although a mere drop of jelly, *improvises* a pocket, or stomach, for the reception of its food, which, for the time being, is differentiated to nutrition. The so-called plant, on the contrary, has its mesentery, as well as its apparatus for aëration, external to the organism. The animal involutes a part of its investing tegument; takes the mesentery, at least, into the inside of the body; and, in the higher orders, the lungs also.

The scientific relations of the two kingdoms are well indicated, therefore, in the terminology which classifies the one as *Exothens*—external livers; and the other as *Endothens*—internal livers.

As to their life, and the elements of organization, they are precisely

the same. The same chemical constituents, the same protoplasm, the same basement of cell-growth, and the same compounding of cells, characterize the development of both. In short, there is but one set of organic creatures. They are all animals, or all plants, as you may please to call them.

Before this simple distinction into endothentic and exothentic, all the difficulties, of discriminating in special cases as to which of the two great kingdoms has the best claim to a particular species, vanish. Those organisms of the boundary-line which could never be located, because sometimes apparently one, and sometimes the other, as motion and volition, seemed to be present or absent, now readily take their places. For instance, the aëthalium—to show the impossibility of a definite boundary—is sometimes observed as a flying vibrio, then a crawling amœba-like drop of sarcode; then, in the still condition, a greenish spherical cell like some protococus; even this mysterious creature need no longer be regarded as amphibious. In every stage it is decidedly exothentic.

What, then, is the distinction, and how does the evolution advance? Let us go back a little. We observe that in plants evolution advances by a folding down of the creature upon itself—an involution. A strip of paper may well represent that type which consists of a single tier or layer of cells, as in ulvaceæ; or even baculate types, as confervæ. This is our biological surface.

Fold it down upon itself, the two surfaces coming in contact soon adhere, and then we have, as we have seen, a creature of two tiers of cells. This begins to look like reducing a loose collection, or a mere association of cells, to a consolidated organization.

Fold the sheet again, and you have another solid, a creature of four tiers of cells, with a distinct axis of growth. This is the type of all the higher cryptogams.

Fold it once more, and you have a type, normally, of eight tiers—the type of the phanerogams.

It is to be noted that every folding develops a new axis of growth at right angles to that of the preceding type, the folding being really the mechanism employed for the evolution of the axis. Involutions do not stop here, for no surfaces come together without a tendency to adhere, especially in the fœtal stage of life when all the elements are plastic; and it is at that period that all variations occur. But, as already noticed, no further involutions, except these three, affect the axis of the whole creature and change the type. To this simple fact of the adhesion of organic surfaces all the innumerable morphological variations may be referred. Upon it depends the success of the surgeon's skill, as well as the analysis of the speculative physiologist. Adhesions of the edges of leaves account for their shapes and sizes. Adhesion by their surfaces causes many wonders, among them the evolution of all carpels, seeds, and fruits. Sometimes, also, there is

adhesion of surfaces confined to a single leaf, as in the *iris*. But these adhesions are all topical, if I may use the word, and do not affect the type and general axis.

Now, this involution, by which the progress of evolution takes place, may, as remarked, and strange to say, be described as a *failure of development*—a failure to unfold into the original type, constituting, by the very failure, a new and higher type. If we watch the development of any leaf from venation, we observe that in some way it was folded down upon itself, or rolled up with its fellows of the same bud, and before coming to adult age it expanded into the recognized form of its order. Let but that expansion fail, and the evolution may be said to fail. A happy failure; for to this we owe the production of grain and fruit—the food of man. Adhesions take place within the buds, which change the leaf-buds into flower-buds. The change is always made in the embryo, while still plastic and capable of being moulded into new forms.

It would be delightful to follow the immortal Linnæus, Wolf, Goethe, and the grand army of enlightened living botanists, who have illustrated this beautiful transcendental history of leaves, and flowers, and fruits; but time forbids at present. Suffice it to say that, so far as the vegetal kingdom is concerned, the doctrines of involution have become the common property of the scientific world.

Let us pass on to the so-called animal kingdom.

And first, as to the bridge we cross. True, it is somewhat the fashion to tell us that here is a great gulf fixed, and no crossing was ever possible. Yet Nature found a bridge somewhere, and we ought not to despair of finding at least some remains of the abutments.

To illustrate this passage from the vegetal to the animal plan of structure, take a hollow India-rubber ball, which may very well represent a cell enlarged a few thousand diameters. It is a perfect image of an external living creature, and is also typical of one stage of the development of the ova of the lower orders of animals—probably of all animals. But it is the adult form of plants. The vital functions of such a cell are all within; and there is no communication with the external world, except by osmotic action. Through this same cell-wall—this same external coat—and by means of it, nutrition and aëration are both carried on. This is an *exothen*.

Now, by pressing the finger upon a part of the elastic coat, a portion of it sinks in, and you have a cup—a cup with double walls and a space between them. This is an involution; and by means of such an involution as this Nature transforms a plant into an animal.

Recently-published observations of Kowalewsky declare that he has seen this sort of transformation actually take place in the growth of the embryo of a creature as high in the scale as the Ascidians. Doubtless, in Nature, the true process was a failure at one point to fill out the rounded fullness of the ball; some contraction, some atrophy,

some failure to grow at a certain spot, while the balance of the creature continues its development, until a wall arises around the constriction and becomes permanent, further growth only increasing the introversion—precisely such a process as we may witness at the hands of a potter when he places a ball of clay upon his wheel. First he flattens the top of his ball; then, as he continues to press upon the point, the adjacent clay rises around it; and next you have a cup. And such a cup-like cell is the type of all endothentic creatures; that is, of all animals.

Naturalists, it is true, regarding only flagrant forms, confine the term *cœlenterate* to one class; those that are *permanently* open-cupped. But, strictly, all differentiate a part of the investing tegument into a cup, for the purpose of carrying about their nutrition; and, however much the cup may be extended and contorted—drawn out into a tube and folded away into some convenient receptacle, and puckered, and tucked, and furnished with a thousand little pockets supplementary—it is all but an extension of that same original internal fold or cup. Finally, in the highest animals, all the principal vital functions are found severally the office of some pocket of the integument *involuted* and shoved out of sight and out of harm's way into the great cavity.

Having obtained for our animal kingdom the cupped cell as a type, we have plain sailing for some time.

In the outset, we may subdivide the kingdom into the *occasionally* cupped and the *permanently* cupped. Those that present the cup as occasion serves, or only in one stage of their evolution, are exemplified in the Rhizopoda. The permanently-cupped include not only those always open-mouthed—the cœlenterata of Mr. Huxley—but, as we have seen, necessarily all of the higher classes.

Observe, again, the India-rubber ball. First, we have the cup. Now, this open cup is mouth—is stomach—is vent—is every thing. Every thing that goes into the creature enters here; all that comes out finds exit by means of this common gap. Soon Nature, so to speak, finds this plan poor economy, and divides off one side, or edge of the cup, for one purpose, another for another purpose, and we find one corner or edge of it devoted to the entrance of nutrition, another to the exit of the *débris*. Nor is this mere speculation. Creatures are actually so constituted, and are seen to develop to this type from the *ovum*. We often see, in cœlenterates, as in sea-anemone, a tendency to the same thing. Now, this very fact of voiding *indigesta* at one angle of the mouth, while the other is receiving a fresh supply of food, produces a constriction in the unused middle region; and the consequence is that here the lips approximate one another, and finally, adhering at the point of contact, a permanent *perinæum-like* septum is formed.

This adhesion completed, nothing more is wanting to exhibit the type of the higher *animalia;* for here is a complete alimentary canal, however short, and a dorsal and a ventral aspect. This is an animal

of one segment, or cell, type of both the cœlenterata and molluscoida of Mr. Huxley, and of all mono-segmental creatures.

Henceforward, this type is the unit of animal organisms, as a simple cell is the unit of primary vegetal life. For want of a better term such a creature may be called a mono-segmentary, consisting of but one segment or unit; while all others are polysegmentarian—consisting of more sections than one.

Nature retains her *habits* very tenaciously. If we have seen her rising to higher and higher types of vegetal structure by adding cell to cell; duplicating cells by division and holding on to them by adhesion; extending them by increase upon one axis into a baculus; upon two axes into thalli; and folding them again into fronds, leaves, and fruit—we no less see her handling this new unit of organization in a similar manner. Ay! the parsimonious *builder* again goes through precisely the same means of progress. She works by compounding; by multiplication of segments; by gemmation; by the evolution of higher types; by a failure to expel the simple segments; until, by adhesions in fœtal life, a more complex creature is formed of multiplied powers.

Here, again, we come to great gulfs and faults in the strata, which naturalists tell us cannot be bridged over. There remain still the three highest types of organic creatures to be accounted for, namely, the *annulosa*, or *articulata*, the *mollusca*, and the *vertebrata*. Our most eminent recent naturalists regard all these as unconnected with preceding forms, and unconnected with one another. Some of the very recent, as Haeckel, endeavor to show a consistent chain here by connecting directly molluscoids with vertebrates; dropping out of the series entirely the two great classes of mollusca and articulata, and leaving their evolution unaccounted for. True, there can be no objection to leaving them out of the chain, if they have no place in it. If we can arrive at vertebrates and man directly from the holothurius, well and good. It would be analogous to other proceedings of Nature, as in the separate evolution of the whole grand vegetal kingdom from the first living germs, in a direction exactly opposite, as it were, to animal evolution. But we should also account for the genesis of the two eccentric classes, and connect them in some way with primordial types.

COLOR IN ANIMALS.

THE variety of coloring in animal life is one of the marvels of Nature, only now beginning to be studied scientifically. It is vain to say that an animal is beautiful, either in symmetry or diversity of color, in order to please the human eye. Fishes in the depth of the Indian seas, where no human eye can see them, possess the most gorgeous tints. One thing is remarkable: birds, fishes, and insects, alone possess

the metallic coloring; while plants and zoophytes are without reflecting shades. The mollusca take a middle path with their hue of mother-of-pearl. What is the reason of these arrangements in the animal kingdom? It is a question which cannot be satisfactorily answered; but some observations have been made which throw light on the subject. One is, that among animals, the part of the body turned toward the earth is always paler than that which is uppermost. The action of light is here apparent. Fishes which live on the side, as the sole and turbot, have the left side, which answers to the back, of a dark tint; while the other side is white. It may be noticed that birds which fly, as it were, bathed in light, do not offer the strong contrast of tone between the upper and lower side. Beetles, wasps, and flies, have the metallic coloring of blue and green, possess rings equally dark all round the body; and the wings of many butterflies are as beautifully-feathered below as above.

On the other hand, mollusca which live in an almost closed shell, like the oyster, are nearly colorless; the larvæ of insects found in the ground or in wood have the same whiteness, as well as all intestinal worms shut up in obscurity. Some insects whose life is spent in darkness keep this appearance all their lives; such as the curious little beetles inhabiting the inaccessible crevasses of snowy mountains, in whose depths they are hidden. They seem to fly from light as from death, and are only found at certain seasons, when they crawl on the flooring of the caves like larvæ, without eyes, which would be useless in the retreats where they usually dwell.

This relation between coloring and light is very evident in the beings which inhabit the earth and the air; those are the most brilliant which are exposed to the sun; those of the tropics are brighter than in the regions around the north-pole, and the diurnal species than the nocturnal; but the same law does not apparently belong to the inhabitants of the sea, which are of a richer shade where the light is more tempered. The most dazzling corals are those which hang under the natural cornices of the rocks and on the sides of submarine grottoes; while some kinds of fish, which are found on the shores as well as in depths requiring the drag-net, have a bright-red purple in the latter regions, and an insignificant yellow brown in the former. Those who bring up gold-fish know well that, to have them finely colored, they must place them in a shaded vase, where aquatic plants hide them from the extreme solar heat. Under a hot July sun they lose their beauty.

The causes to which animal coloring is due are very various. Some living substances have it in themselves, owing to molecular arrangement, but usually this is not the case; the liveliest colors are not bound up with the tissues. Sometimes they arise from a phenomenon like that by which the soap-bubble shows its prismatic hues; sometimes there is a special matter called pigment which is united with the or-

ganic substance. Such is the brilliant paint, carmine, which is the pigment of the cochineal insect, and the red color of blood, which may be collected in crystals, separate from the other particles to which it is united.

Even the powder not unknown to ladies of fashion is one of Nature's beautifying means. That which is left on the hands of the ruthless boy, when he has caught a butterfly, is a common instance; but there are birds, such as the large white cockatoo, which leave a white powder on the hands. An African traveller speaks of his astonishment on a rainy day to see his hands reddened by the moist plumage of a bird he had just killed. The most ordinary way, however, in which the pigment is found is when it exists in the depths of the tissues reduced to very fine particles, best seen under the microscope. When scattered, they scarcely influence the shade; but, when close together, they are very perceptible. This explains the color of the negro: under the very delicate layer of skin which is raised by a slight burn there may be seen abundance of brown pigment in the black man. It is quite superficial, for the skin differs only from that of the European in tone; it wants the exquisite transparency of fair races. Among these, the colors which impress the eye do not come from a flat surface, but from the different depths of layers in the flesh. Hence the variety of rose and lily tints according as the blood circulates more or less freely; hence the blue veins, which give a false appearance, because the blood is red; but the skin thus dyes the deep tones which lie beneath it; tattooing with Indian-ink is blue, blue eyes owe their shade to the brown pigment which lines the other side of the iris, and the muscles seen under the skin produce the bluish tone well known to painters.

The chemical nature of pigment is little known; the sun evidently favors its development in red patches. Age takes it away from the hair when it turns white, the coloring-matter giving place to very small air-bubbles. The brilliant white of feathers is due to the air which fills them. Age, and domestic habits exchanged for a wild state, alter the appearance of many birds and animals; in some species the feathers and fur grow white every year before falling off and being renewed; as in the ermine, in spring the fur which is so valued assumes a yellow hue, and, after a few months, becomes white before winter.

It would, however, be an error to suppose that all the exquisite metallic shades which diaper the feathers of birds and the wings of butterflies arise from pigments; it was a dream of the alchemists to try to extract them. Their sole cause is the play of light, fugitive as the sparkles of the diamond. When the beautiful feathers on the breast of a humming-bird are examined under the microscope, it is astonishing to see none of the shades the mystery of which you would penetrate. They are simply made of a dark-brown opaque substance not unlike those of a black duck. There is, however, a remarkable arrangement; the barb of the feather, instead of being a fringed

stem, offers a series of small squares of horny substance placed point to point. These plates, of infinitesimal size, are extremely thin, brown, and, to all appearance, exactly alike, whatever may be the reflection they give. The brilliant large feathers of the peacock are the same; the plates are only at a greater distance, and of less brightness. They have been described as so many little mirrors, but that comparison is not correct, for then they would only give back light without coloring it. Neither do they act by decomposing the rays which pass through them, for then they would not lose their iris tints under the microscope. It is to metals alone that the metallic plumage of the humming-birds can be compared; the effects of the plates in a feather are like tempered steel or crystallized bismuth. Certain specimens emit colors very variable under different angles, the same scarlet feather becoming, when turned to ninety degrees, a beautiful emerald green.

The same process which Nature has followed in the humming-bird is also found in the wing of the butterfly. It is covered with microscopic scales, which play the part of the feather, arranged like the tiles of a house, and taking the most elegant forms. They also lose their color under magnifying power, and the quality of reflection shows that the phenomena are the same as in feathers. There is, however, a difference in the extent of the chromatic scale. While the humming-bird partakes in its colors of the whole of the spectrum from the violet to the red, passing through green, those of the butterfly prefer the more refrangible ones from green to violet, passing through blue. The admirable lilac shade of the *Morpho menelas* and the *Morpho cypris* is well known, and the wings of these butterflies have been used by the jewelers, carefully laid under a thin plate of mica, and made into ornaments. A bright green is not uncommon, but the metallic red is rare, excepting in a beautiful butterfly of Madagascar, closely allied to one found in India and Ceylon. The latter has wings of a velvet black with brilliant green spots; in the former, these give place to a mark of fiery red.

There is the same difference between the metallic hues of creatures endowed with flight and the iris shades of fishes, that there is between crystallized bismuth and the soft reflections of the changing opal. To have an idea of the richness of the fish, it is only necessary to see a net landed filled with shad or other bright fish. It is one immense opal, with the same transparency of shade seen through the scales, which afford the only means of imitating pearls. It is due, however, not to the scales, but to extremely thin layers lying below the scales under the skin and round the blood-vessels, which look like so many threads of silver running through the flesh. Réaumur first noticed and described them; sometimes their form is as regular as that of a crystal, and of infinitesimal size and thickness. The art of the makers of false pearls is to collect these plates in a mass from the fish, and

make a paste of them with the addition of glue, which is pompously named "Eastern essence." This is put inside glass beads, and gives them the native whiteness of pearls.

Many observations have been made lately by our naturalists as to the defense which color supplies to animals: hares, rabbits, stags, and goats, possess the most favorable shade for concealing them in the depths of the forest or in the fields. It is well known that when the Volunteer corps were enrolled, and the most suitable color for the riflemen was discussed, it was supposed to be green. Soldiers dressed in different shades were placed in woods and plains, to try which offered the best concealment. Contrary to expectation, that which escaped the eyes of the enemy was not green, but the fawn color of the doe. Among hunting quadrupeds, such as the tiger, the leopard, the jaguar, the panther, there is a shade of skin which man has always been anxious to appropriate for his own use. The old Egyptian tombs have paintings of the negroes of Soudan, their loins girt with the fine yellow skins for which there is still a great sale. All the birds which prey upon the smaller tribes, and fishes like the shark, are clothed in dead colors, so as to be the least seen by their victims.

There is an animal which, for two thousand years, has excited the curiosity and superstition of man by its change of color—that is, the chameleon. No reasonable observation was ever made upon it, until Perrault instituted some experiments in the seventeenth century. He observed that the animal became pale at night, and took a deeper color when in the sun, or when it was teased; while the idea that it took its color from surrounding objects was simply fabulous. He wrapped it in different kinds of cloth, and once only did it become paler when in white. Its colors were very limited, varying from gray to green and greenish brown.

Little more than this is known in the present day; under our skies it soon loses its intensity of color. Beneath the African sun, its livery is incessantly changing; sometimes a row of large patches appears on the sides, or the skin is spotted like a trout, the spots turning to the size of a pin's head. At other times, the figures are light on a brown ground, which a moment before were brown on a light ground, and these last during the day. A naturalist speaks of two chameleons which were tied together on a boat in the Nile, with sufficient length of string to run about, and so always submissive to the same influences of light, etc. They offered a contrast of color, though to a certain degree alike; but, when they slept under the straw chair which they chose for their domicile, they were exactly of the same shade during the hours of rest—a fine sea-green that never changed. The skin rested, as did the brain, so that it seemed probable that central activity, thought, will, or whatever name is given, has some effect in the change of color. The probability is that, as they become pale, the pigment does not leave the skin, but that it is collected in spheres

too small to affect our retina, which will be impressed by the same quantity of pigment when more extended.

It is undoubtedly the nerves which connect the brain with organs where the pigment is retained. By cutting a nerve, the coloring-matter is paralyzed in that portion of the skin through which the nerve passes, just as a muscle is isolated by the section of its nerve. If this operation be performed on a turbot when in a dark state, and thrown into a sandy bottom, the whole body grows paler, excepting the part which cannot receive cerebral influence. The nerves have, in general, a very simple and regular distribution; if two or three of these are cut in the body of the fish, a black transversal band following the course of the nerve will be seen; while, if the nerve which animates the head is thus treated, the turbot, growing paler on the sand, keeps a kind of black mask, which has a very curious effect.

These marks will remain for many weeks, and what may be called paralysis of color has been remarked in consequence of illness or accident. Such was seen in the head of a large turbot, the body being of a different color. It was watched, and died after a few days, evidently of some injury which it had received. The subject offers a field of immense inquiry; the chemical and physical study of pigments, the conditions which regulated their appearance, their intensity, and variations under certain influences; the want of them in albinos, and the exaggerated development in other forms of disease. To Mr. Darwin, and to M. Ponchet, in France, the subject is indebted for much research, which will no doubt be continued as occasion offers.—*Chambers's Journal.*

AN ESTIMATE OF DARWIN.

By Professor ASA GRAY.

TWO British naturalists, Robert Brown and Charles Darwin, have, more than any others, impressed their influence upon Science in this nineteenth century. Unlike as these men and their works were and are, we may most readily subserve the present purpose in what we are called upon to say of the latter by briefly comparing and contrasting the two.

Robert Brown died sixteen years ago, full of years and scientific honors, and he seems to have finished, several years earlier, all the scientific work that he had undertaken. To the other, Charles Darwin, a fair number of productive years may yet remain, and are earnestly hoped for. Both enjoyed the great advantage of being all their lives long free from any exacting professional duties or cares, and so were able in the main to apply themselves to research without distraction and according to their bent. Both, at the beginning of

their career, were attached to expeditions of exploration in the Southern Hemisphere, where they amassed rich stores of observation and materials, and probably struck out, while in the field, some of the best ideas which they subsequently developed. They worked in different fields and upon different methods; only in a single instance, so far as we know, have they handled the same topic; and in this the more penetrating insight of the younger naturalist into an interesting general problem may be appealed to in justification of a comparison which some will deem presumptuous. Be this as it may, there will probably be little dissent from the opinion that the characteristic trait common to the two is an unrivaled scientific sagacity. In this these two naturalists seem to us, each in his way, preëminent. There is a characteristic likeness, too—underlying much difference—in their admirable manner of dealing with facts closely and at first hand, without the interposition of the formal laws, vague ideal conceptions, or "glittering generalities," which some philosophical naturalists make large use of.

A likeness may also be discerned in the way in which the works or contributions of predecessors and contemporaries are referred to. The brief historical summaries prefixed to many of Mr. Brown's papers are models of judicial conscientiousness. And Mr. Darwin's evident delight at discovering that some one else has "said his good things before him," or has been on the verge of uttering them, seemingly equals that of making the discovery himself. It reminds one of Goethe's insisting that his views in morphology must have been held before him and must be somewhere on record, so obviously just and natural did they appear to him.

Considering the quiet and retired lives led by both these men, and the prominent place they are likely to occupy in the history of Science, the contrast between them as to contemporary and popular fame is very remarkable. While Mr. Brown was looked up to with the greatest reverence by all the learned botanists, he was scarcely heard of by any one else; and out of botany he was unknown to Science except as the discoverer of the Brownian motion of minute particles, which discovery was promulgated in a privately-printed pamphlet that few have ever seen. Although Mr. Darwin had been for twenty years well and widely known for his "Naturalist's Journal," his works on "Coral Islands," on "Volcanic Islands," and especially for his researches on the Barnacles, it was not till about fifteen years ago that his name became popularly famous. Ever since no scientific name has been so widely spoken. Many others have had hypotheses or systems named after them, but no one else, that we know of, a department of bibliography. The nature of his latest researches accounts for most of the difference, but not for all. The Origin of Species is a fascinating topic, having interests and connections with every branch of Science, natural and moral. The investigation of recondite affinities is very dry and special; its questions, processes, and results alike—al-

though in part generally presentable in the shape of morphology—are mainly, like the higher mathematics, unintelligible except to those who make them a subject of serious study. They are especially so when presented in Mr. Brown's manner. Perhaps no naturalist ever recorded the results of his investigations in fewer words and with greater precision than Robert Brown: certainly no one ever took more pains to state nothing beyond the precise point in question. Indeed, we have sometimes fancied that he preferred to enwrap rather than to explain his meaning; to put it into such a form that, unless you follow Solomon's injunction and dig for the wisdom as for hid treasure, you may hardly apprehend it until you have found it all out for yourself, when you will have the satisfaction of perceiving that Mr. Brown not only knew all about it, but had put it upon record long before. Very different from this is the way in which Mr. Darwin takes his readers into his confidence, freely displays to them the sources of his information and the working of his mind, and even shares with them all his doubts and misgivings, while in a clear and full exposition he sets forth the reasons which have guided him to his conclusions. These you may hesitate or decline to adopt, but you feel sure that they have been presented with perfect fairness; and, if you think of arguments against them, you may be confident that they have all been duly considered before.

The sagacity which characterizes these two naturalists is seen in their success in finding decisive instances, and in their sure insight into the meaning of things. As an instance of the latter on Mr. Darwin's part, and a justification of our venture to compare him with the *facile princeps botanicorum*, we will, in conclusion, allude to the single instance in which they took the same subject in hand. In his papers on the organs and modes of fecundation in Orchideæ and Asclepiadeæ, Mr. Brown refers more than once to C. K. Sprengel's almost forgotten work, shows how the structure of the flowers in these orders largely requires the agency of insects for their fecundation, and is aware that "in Asclepiadeæ . . . the insect so readily passes from one corolla to another that it not unfrequently visits every flower of the umbel." He must also have contemplated the transport of pollen from plant to plant by wind and insects, and we know from another source that he looked upon Sprengel's ideas as far from fantastic. Yet, instead of taking the single forward step which now seems so obvious, he even hazarded the conjecture that the insect-forms of some Orchideous flowers are intended to deter rather than to attract insects. And so the explanation of all these and other extraordinary structures, as well as of the arrangement of blossoms in general, and even the very meaning and need of sexual propagation, were left to be supplied by Mr. Darwin. The aphorism "Nature abhors a vacuum" is a characteristic specimen of the Science of the middle ages. The aphorism "Nature abhors close fertilization," and the demonstration of the principle,

belong to our age, and to Mr. Darwin. To have originated this, and also the principle of Natural Selection—the truthfulness and importance of which are evident the moment it is apprehended—and to have applied these principles to the system of Nature in such a manner as to make, within a dozen years, a deeper impression upon natural history than has been made since Linnæus, is ample title for one man's fame.

There is no need of our giving any account or of estimating the importance of such works as the "Origin of Species by means of Natural Selection," the "Variation of Animals and Plants under Domestication," the "Descent of Man, and Selection in relation to Sex," and the "Expression of the Emotions in Man and Animals"—a series to which we may hope other volumes may in due time be added. We would rather, if space permitted, attempt an analysis of the less known but not less masterly subsidiary essays, upon the various arrangements for insuring cross-fertilization in flowers, for the climbing of plants, and the like. These, as we have heard, may before long be reprinted in a volume, and supplemented by some long-pending but still unfinished investigations upon the action of Dionæa and Drosera—a capital subject for Mr. Darwin's handling.

A propos to these papers, which furnish excellent illustrations of it, let us recognize Darwin's great service to Natural Science in bringing back to it Teleology: so that, instead of Morphology *versus* Teleology, we shall have Morphology wedded to Teleology. To many, no doubt, Evolutionary Teleology comes in such a questionable shape as to seem shorn of all its goodness; but they will think better of it in time, when their ideas become adjusted, and they see what an impetus the new doctrines have given to investigation. They are much mistaken who suppose that Darwinism is only of speculative importance and perhaps transient interest. In its working applications it has proved to be a new power, eminently practical and fruitful.

And here, again, we are bound to note a striking contrast to Mr. Brown, greatly as we revere his momory. He did far less work than was justly to be expected from him. Mr. Darwin not only points out the road, but labors upon it indefatigably and unceasingly. A most commendable *noblesse oblige* assures us that he will go on while strength (would we could add health!) remains. The vast amount of such work he has already accomplished might overtax the powers of the strongest. That it could have been done at all under constant infirm health is most wonderful.

Appended is a full List of Mr. Darwin's Works.

GENERAL WORKS.

Journal of Researches into the Natural History and Geology of the Countries visited by H. M. S. Beagle, 1845.

On the Origin of Species by Means of Natural Selection, 1859.

This was preceded by a sketch, entitled "On the Variation of Organic Beings in a State of Nature;" published in the *Journal of the Linnæan Society*, vol. iii. (Zoology), 1859, p. 46.

The Variation of Plants and Animals under Domestication. 2 vols. 1868.

The Descent of Man, and Selection in relation to Sex. 2 vols. 1871.

The Expression of the Emotions in Man and Animals. 1872.

ZOOLOGICAL WORKS.

The Zoology of the Voyage of H. M. S. Beagle, edited and superintended by C. Darwin, 1840; consisting of five parts.

A Monograph of the Cirripedia, Part 1, Lepadidæ; Ray Society, 1851, pp. 400.

A Monograph of the Cirripedia, Part 2, the Balanidæ; Ray Society, 1854, pp. 684.

A Monograph of the Fossil Lepadidæ; Pal. Society, 1851, pp. 86.

A Monograph of the Fossil Balanidæ and Verrucidæ; Pal. Society, 1854, pp. 44.

Observations on the Structure of the Genus Sagitta; Annals of Natural History, vol. xiii., 1844.

Brief Descriptions of Several Terrestrial Phanariæ, and of Some Marine Species; Annals of Natural History, vol. xiv., 1844, p. 241.

BOTANICAL WORKS.

On the Various Contrivances by which British and Foreign Orchids are fertilized, 1862.

On the Movements and Habits of Climbing Plants; Journal Linnæan Society, vol. ix., 1865 (Botany), p. 1.—This paper has also been published as a separate work.

On the Action of Sea-water on the Germination of Seeds; Journal Linnæan Society, vol. i., 1857 (Botany), p. 130.

On the Agency of Bees in the Fertilization of Papilionaceous Flowers; Annals Natural History, vol. ii., 1858, p. 459.

On the Two Forms or Dimorphic Condition of the Species of Primula; Journal Linnæan Society, vol. vi., 1862 (Botany), p. 77.

On the Existence of Two Forms and their Reciprocal Sexual Relations in the Genus Linum; Journal Linnæan Society, vol. vii., 1863 (Botany), p. 69.

On the Sexual Relations of the Three Forms of Lythrum; Journal Linnæan Society, vol. viii., 1864, p. 169.

On the Character and Hybrid-like Nature of the Illegitimate Offspring of Dimorphic and Trimorphic Plants; Journal Linnæan Society, vol. x., 1867 (Botany), p. 393.

On the Specific Difference between *Primula veris* and *P. vulgaris*,

and on the Hybrid Nature of the Common Oxslip; Journal Linnæan Society, vol. x., 1867 (Botany), p. 437.

Notes on the Fertilization of Orchids; Annals Natural History, September, 1869.

GEOLOGICAL WORKS.

The Structure and Distribution of Coral-reefs, 1842; pp. 214.

Geological Observations on Volcanic Islands, 1844; pp. 175.

Geological Observations on South America, 1846; pp. 279.

On the Connection of the Volcanic Phenomena in South America, etc.; Transactions of Geological Society, vol. v.; read March, 1838.

On the Distribution of the Erratic Bowlders in South America; Transactions of Geological Society, vol. vi., read April, 1841.

On the Transportal of Erratic Bowlders from a Lower to a Higher Level; Journal Geological Society, 1848, p. 315.

Notes on the Ancient Glaciers of Caernarvonshire; Philosophical Magazine, vol. xxi., 1842, p. 180.

On the Geology of the Falkland Islands; Journal Geological Society, 1846, pp. 267.

On a Remarkable Bar of Sandstone off Pernambuco; Philosophical Magazine, October, 1841, p. 257.

On the Formation of Mould; Transactions of Geological Society, vol. v., p. 505; read November, 1837.

On the Parallel Roads of Glen Roy; Transactions of Philosophical Society, 1839, p. 39.

On the Power of Icebergs to make Grooves on a Submarine Surface; Philosophical Magazine, August, 1855.

An Account of the Fine Dust which often falls on Vessels in the Atlantic Ocean; Proceedings of Geological Society, 1845, p. 26.

Origin of the Saliferous Deposits of Patagonia; Journal of Geological Society, vol. ii., 1838, p. 127.

Part Geology; Admiralty Manual of Scientific Inquiry, 1849. Third edition, 1859.—*Nature.*

SKETCH OF THE LIFE OF DR. PRIESTLEY.

IT is unnecessary to call attention to the eloquent and impressive lecture by Dr. Draper which opens the present number of THE POPULAR SCIENCE MONTHLY. It will be read with avidity and pleasure by all classes as a beautiful tribute to a noble man, and as treating one of the most brilliant of scientific discoveries with the true poetic inspiration which well befits so grand a theme. Dr. Draper's statement is as fresh and felicitous as if his lecture had just been prepared to commemorate the centennial of the Discovery of Oxygen, and but few will suspect on perusing it that it was delivered a quarter

of a century ago, before the medical students of the New York University; of course with no reference whatever to the present occasion. It was privately printed by the class for their own use, and has never before been given to the public. Its perusal cannot fail to sharpen the interest of readers to know more of the personality of the remarkable man who made the greatest of all chemical discoveries, and to whose eventful career there attaches so romantic an interest. The materials of the following sketch are compiled from the summary of Priestley's work given by Dr. Thomas Thomson, in his history of chemistry in 1829, and from the "Autobiography and Life of Priestley," published by his son in 1807.

Joseph Priestley was born in 1733, near Leeds, in Yorkshire, England. His father was a poor mechanic, a cloth-dresser, and his mother the daughter of a farmer. He was the eldest child, and, having lost his mother when six years of age, he went to live with his aunt, a woman in good circumstances, without children, and who adopted him. She was a dissenter, and her house was the resort of all the dissenting ministers in the country; and it is important to observe that, although a very religious woman, she was so thoroughly liberal as to welcome even the most unorthodox clergymen to her hospitality, and to encourage the widest latitude of opinion—a circumstance which probably determined the career of her nephew. Joseph was sent to a public school in the neighborhood, and at sixteen had made considerable progress in Latin, Greek, and Hebrew. He had thoughts of studying for a clergyman, but, his health failing, he turned his attention to trade, with the idea of settling in Lisbon as a merchant. This induced him to study the modern languages, and he learned French, Italian, and German, without a master. Recovering his health, he abandoned the business scheme, and resumed his former plan of becoming a minister. Having made some progress in mechanical philosophy and metaphysics, and dipped into Chaldee, Syriac, and Arabic, and learned a system of short-hand, in 1752 he was sent to the academy at Daventry. Here he spent three years, engaged keenly in studies connected with divinity, and wrote some of his earliest theological tracts. Freedom of discussion was admitted to its full extent in this academy, and the discussions among the students were conducted with perfect good-humor on both sides. Young Priestley, as he tells us himself, usually supported the heterodox opinion; but he never at any time, as he assures us, advanced arguments which he did not believe to be good, or supported an opinion which he did not consider as true.

When he left the academy, he settled at Needham, in Suffolk, as an assistant in a small, obscure dissenting meeting-house, at a salary of $150 a year. From the outset he was an original and independent thinker, and as a preacher he gave free and conscientious expression to the views he was led to adopt. It could hardly be otherwise than that such a course would be distasteful to many people whose religion

consisted in the acceptance of a system of dogmatic theology. Hence his hearers fell off at Needham, from their dislike of his theological opinions. He attempted a school, but the scheme failed because of his unpopularity. Several pulpit vacancies occurred in his vicinity, but he was treated with contempt and thought unworthy to fill any of them. Even the dissenting clergy in the neighborhood considered it a degradation to associate with him, and durst not ask him to preach, not from any dislike to his opinions, for several of them thought as freely as he did, but because the genteeler part of their audiences always absented themselves when he appeared in the pulpit. A good many years afterward, when his reputation was high, he preached in the same place, and multitudes flocked to hear the very same sermons which they had formerly listened to with contempt! Leaving Needham, he went to Nantwich, where he preached for three years; and, by teaching twelve hours a day much of the time, was able to purchase a few books and some philosophical instruments, as a small air-pump, an electrical machine, etc. These he taught his eldest scholars to keep in order and manage; and by entertaining their parents and friends with experiments, in which the scholars were generally the operators, and sometimes the lecturers too, he considerably extended the reputation of his school. At this time he wrote a grammar, which is said to have been an excellent work; but the favorable reception of Dr. Louth's grammar, published about the same time, prevented its general circulation. He practised flute-playing, and, although not a proficient, he found it serviceable as a recreation, and recommended music to all studious persons for this purpose.

From Nantwich he went to Warrington in 1761, where he spent six years in teaching. He here entered zealously upon the prosecution of his systematic studies and his researches. He wrote a variety of works, prominent among which was his history of electricity. In relation to the origin of this work he remarks: "On going to London[1] I met Dr. Franklin, and was led to attend to the subject of experimental philosophy more than I had done before; and having composed all the lectures I had occasion to deliver, and finding myself at liberty for any undertaking, I mentioned to Dr. Franklin an idea that had occurred to me of writing the history of discoveries in electricity, which was his favorite study. This I told him might be a useful work, and that I would willingly undertake it, provided I could be furnished with the books necessary for the purpose. This he readily undertook, and, my other friends assisting him, I set about the work without having the least idea of doing any thing more than writing a distinct and methodical account of all that had been done by others. Having, however, a pretty good machine, I was led, in the course of my writing

[1] He always spent one month in every year in London, which was of great use to him. He generally made additions to his library and his chemical apparatus. A new turn was given to his ideas, and new and useful acquaintances were made.

the history, to endeavor to ascertain several facts which were disputed; and this led me, by degrees, into a large field of original experiments, in which I spared no expense that I could possibly furnish. These experiments employed a great proportion of my leisure time; and yet, before the complete expiration of the year in which I gave the plan of my work to Dr. Franklin, I sent him a copy of it in print." It was this work which first brought him into notice as an experimental philosopher and procured for him the title of Doctor of Laws from the University of Edinburgh, and led to his being made a member of the Royal Society, from which he received its greatest honor, the Copley Medal. He married, while at Warrington, in 1763, the daughter of Mr. Isaac Wilkinson, an iron-master. Although not settled as a clergyman at Warrington, he kept up the habit of preaching, and was here ordained. Dr. Priestley stammered so badly that he sometimes thought he must give up preaching, but he at length measurably conquered the defect by the daily habit of slow reading in a loud voice. He recognized that this defect of delivery saved him from the temptation of trying to be an orator.

In 1767, Dr. Priestley went to Leeds and took charge of a chapel, and here he engaged keenly in the study of theology, and produced a great number of controversial works. He commenced his investigations on airs, and published a history of the discoveries in relation to vision, light, and colors, as the first part of a general history of experimental philosophy, which was not continued, because it failed to pay expenses. Here, likewise, he commenced the publication of a periodical, the *Repository*, devoted to theological subjects. Among numerous other things, he wrote an "Essay on Government," an enlarged "English Grammar," a "Familiar Introduction to the Study of Electricity," a "Treatise on Perspective and Chart of History," and, at the request of Drs. Franklin and Fothergill, an "Address to Dissenters on the Subject of the Difference with America."

It was in 1769, while at Leeds, that Dr. Priestley came into conflict with Blackstone, the celebrated author of the commentaries on the laws of England. Having, in that work, approved the statutes of Edward VI. and Queen Elizabeth, denouncing the penalties of confiscation and imprisonment against all who speak in derogation of the Book of Common Prayer, and justified the continuance of these penalties, Dr. Priestley replied to him, pointing out the injustice of such statutes, and the illiberality of those who undertake to defend them. He also convicted Dr. Blackstone of inaccuracy in the statement of historical facts. To this the learned lawyer made a reply, disavowing the sentiment that "the spirit, the principles, and the practices of the sectaries, are not calculated to make men good subjects;" and generously promised to cancel the offensive paragraphs in the future editions of his work. Dr. Priestley addressed him a handsome letter, and the controversy was brought to an amicable conclusion.

It was while at Leeds, in the year 1771, that Dr. Priestley was invited by Sir Joseph Banks, who had charge of the scientific arrangements, to accompany Captain Cook's second expedition to the South Seas, in the capacity of astronomer, and accepted the invitation. He was, however, rejected by the Board of Longitude, on account of his religious opinions, which called from him the following pointed letter to Sir Joseph Banks:

"LEEDS, *December* 10, 1771.

"DEAR SIR: After the letter which I received about a fortnight ago, from Mr. Eden, who informed me that he wrote at your request, I cannot help saying that yours and his, which I have now received, appear a little extraordinary. In the former letter there was far from being the most distant hint of any objection to me provided I would consent to accompany you. You now tell me that, as the different professors of Oxford and Cambridge will have the naming of the persons, and they are all clergymen, they may possibly have some scruples on the head of religion; and that, on this account, you do not think you could get me nominated at any rate, much less on the terms that were first mentioned to me. Now, what I am, and what they are, with respect to religion, might easily have been known before the thing was proposed to me at all. Besides, I thought that this had been a business of philosophy, and not of divinity. If, however, this be the case, I shall hold the Board of Longitude in extreme contempt, and make no scruple of speaking of them accordingly, taking for granted that you have just ground for your suspicions. I most sincerely wish you a happy voyage, as I doubt not it will be greatly to the emolument of science; but I am surprised that the persons who have the chief influence in this expedition, having (according to your representation) minds so despicably illiberal, should give any countenance to so noble an undertaking. I am truly sorry that a person of your disposition should be subject to a choice restricted by such narrow considerations. I am, etc., J. PRIESTLEY."

After six years' stay at Leeds, Dr. Priestley left, and entered into a relation with Lord Shelburne, afterward Marquis of Lansdowne, the arrangement being brought about by Dr. Price. Priestley was to be librarian and companion to his lordship, with a salary of $1,250 a year, and a house, and a life-pension of $750 a year in case of separation. His family was situated near Lord Shelburne's country-seat, where he spent his summers, but a great part of the winter was passed in his lordship's house in London. Priestley traveled with Shelburne on the Continent, and spent some time in Paris, where he says he found "all the philosophical persons, to whom I was introduced at Paris, unbelievers in Christianity, and even professed atheists. As I chose on all occasions to appear as a Christian, I was told by some of them that I was the only person they had ever met with, of whose understanding they had any opinion, who professed to believe in Christianity. But, on interrogating them on the subject, I soon found that they had given no proper attention to it, and did not really know what Christianity was. This was also the case with a great part of the company that I saw at Lord Shelburne's." While in this situation, Dr. Priestley had much leisure for scientific research, and was active in

prosecuting his experiments. Lord Shelburne allowed him $200 a year extra to assist in this object. This arrangement continued seven years, when his lordship seems to have got tired of it, and a separation resulted, although it was entirely amicable. Some years afterward his lordship proposed to renew the relation, but Priestley declined.

Dr. Priestley then took up his residence in Birmingham, where he assumed charge of a congregation, and continued for several years engaged in his theological and scientific investigations. His apparatus, by the liberality of his friends, had become excellent, and his income was now so good that he could prosecute his researches with freedom. He here continued his *Theological Repository*, and published a variety of tracts on his peculiar opinions in religion and upon the history of the primitive Church.

Dr. Priestley had commenced the investigation of gases while living at Leeds, and had there prepared the first volume of his researches upon air. These researches were continued during his residence with Lord Shelburne, and the last three volumes of his experiments on air were printed after he was settled in Birmingham; and while here he also contributed various papers to the Transactions of the Royal Society. No man ever entered upon any undertaking with less apparent means of success than Dr. Priestley did on the investigation of *airs*. He was unacquainted with chemistry, excepting that he had some years before attended an elementary course delivered by Mr. Turner, of Liverpool. He had no apparatus, and knew nothing of chemical experimenting, and was without means to carry on investigations. These adverse conditions may, however, have been serviceable as he entered upon a new field of chemistry, where apparatus had to be invented, and the arrangement devised by him for the manipulation of gases is unsurpassed in simplicity, and has been in use ever since. The first of his discoveries was nitrous gas, the properties of which he ascertained with much sagacity, and applied it to the analysis of air. It contributed very much to all subsequent investigations in pneumatic chemistry, and may be said to have led to our present knowledge of the constitution of the atmosphere. It was while living with Lord Shelburne that he made his grand discovery of oxygen gas, and established the properties of that remarkable body. He showed its power of supporting combustion better, and animal life longer, than the same volume of common air. Lavoisier laid claim to the discovery, but Dr. Priestley informs us that he prepared this gas in M. Lavoisier's house in Paris, and showed him the method of procuring it in the year 1774, which is a considerable time before the date assigned by Lavoisier for his pretended discovery. Scheele, however, the Swedish chemist, actually obtained this gas without any previous knowledge of what Priestley had done, but the book containing this discovery was not published till three years after Priestley's process became known to the public.

Dr. Priestley first made known sulphurous acid, fluosilicic acid, and

muriatic acid, and pointed out easy methods of procuring them; he describes with exactness the most remarkable properties of each. He likewise pointed out the existence of carburetted hydrogen gas, though he made but few experiments to determine its nature. He also discovered protoxide of nitrogen, and, after he came to this country, carbonic-oxide gas. Though not strictly the discoverer of hydrogen, yet his experiments on it were highly interesting, and contributed to the progress of the science. Nitrogen had been previously discovered, but we are indebted to him for a knowledge of most of its properties. To him also we owe the knowledge of the fact that an acid is formed when the electric sparks are made to pass for some time through a given bulk of common air; a fact which led afterward to Mr. Cavendish's great discovery of the composition of nitric acid. His experiments on the influence of plants and animals upon the air were interesting and important.

It has been said of Dr. Priestley that he was fond of controversy, yet he never sought it, and, if he participated in it, it was generally because it was thrust upon him, and he became the defendant rather than the assailant. His discussions, so far as they depended upon himself, were commonly carried on without anger, and he was never malicious or even sarcastic, unless provoked. Had he been of a quarrelsome disposition, it would have been evinced in the numerous and changing relations with the people among whom he lived, but he never quitted a situation but with the sincere regrets of those among whom he had dwelt, and with parting testimonies of their affectionate approbation of his conduct. He was, however, a man of strong convictions upon subjects of the highest interest, and of great intellectual force, and, what is still more important, he represented an unpopular class and held opinions that were generally regarded in England with detestation. These facts go far to explain the controversies in which he was engaged, without attributing to him a love of disputation.

It was while in Birmingham that he was drawn into conflict with the established clergy of the place, which became embittered, and, ending in violence and persecution, darkened the close of his life. The utmost that can be said in condemnation of Priestley at this time is, that he expressed his opinions with a degree of freedom which, though it would have been of little consequence at any former period, was ill-suited to the temper of the times. We have seen that Dr. Priestley had published an essay on the first principles of civil government. In this he laid down as the foundation of his reasoning that "it must be understood, whether it be expressed or not, that all people live in society for their mutual advantage; so that the good and happiness of the members, that is the majority of the members of any state, is the great standard by which every thing relating to that state must be finally determined; and, though it may be supposed that a body of people may be bound by a voluntary resignation of all their rights to a

single person, it can never be supposed that the resignation is obligatory on their posterity, because it is manifestly contrary to the good of the whole that it should be so." From this first principle he deduces all his political maxims. Kings, senators, and nobles, are merely the servants of the public; and, when they abuse their power, in the people lies the right of deposing and consequently of punishing them. He examines the expediency of hereditary sovereignty, of hereditary rank and privileges, of the duration of Parliament, and of the right of voting, with an evident tendency to democratic principles. Though he approved of a republic in the abstract, yet, considering the prejudices and habits of the people of Great Britain, he laid it down as a principle that their present form of government was best suited to them. He was an enemy to all violent reforms, and thought that the change ought to be brought about gradually and peaceably.

These principles excited no alarm and drew but little attention at the time of their publication in 1788, but the perturbation occasioned throughout Europe by the French Revolution was very conspicuous in England, and it was during the state of public irritability upon that subject that Dr. Priestley's teachings were made a source of public alarm. Opposed to a state church, liberal in religion, and advocating freedom of thought and liberty of discussion, he was represented as the enemy of the government and the foe of religion. The French recognized his eminent position as a champion of liberal thought, and he was honored by being made a citizen of France, and a member of the Assembly. This made him in a high degree obnoxious at home, and was laid hold of by his antagonists to convince the people that he was an enemy to his country, that he had abjured his rights as an Englishman, and had adopted the principles of the hereditary enemies of Great Britain. The clergy of the English Church, who began about this time to be alarmed for their establishment, of which Dr. Priestley was the open enemy, were particularly active; the press teemed with their denunciations of him, and the minds of their hearers were inflamed against him. This vicious state of feeling at length broke bounds and issued in violence. On the day of the anniversary of the French Revolution, in 1791, there was a riot in Birmingham, in which Dr. Priestley's meeting-house and dwelling-house were burned, his library and apparatus destroyed, and many manuscripts, the fruits of years of industry, were consumed in the conflagration. The houses of several of his friends shared the same fate, and his son was only saved from death by the care of a friend who concealed him for several days. Dr. Priestley was obliged to make his escape to London, and a seat was taken for him in the mail-coach under a borrowed name. Such was the ferment against him that it was believed he would not have been safe anywhere else, and his friends would not allow him for several weeks to walk through the streets. He was invited to Hackney to succeed the celebrated Unitarian clergyman Dr. Price. He ac-

cepted, but such was the dread of his unpopularity that nobody would let him have a house, from an apprehension that it would be burned by the populace. He was obliged to get a friend to take the lease for him, and it was with the utmost difficulty that he could prevail with the landlord to transfer the lease to him, as he alleged that he was not only afraid that it would be demolished, but that his own residence, twenty miles off, would go next. When he got settled, his friends living near were advised to remove their valuable effects. Servants could not be induced to stay with him, and his neighbors were in fear of damage by his presence. The members of the Royal Society, of which he was a fellow, declined admitting him to their company, and he was obliged to withdraw his name from the Society. His eldest son was in business in Manchester with a partner who, although a man of liberality himself, was so panic-struck by the state of the public mind that he dissolved the business connection. Dr. Priestley was burned in effigy with Paine, and threatened and denounced in private letters. At a dinner of the prebendaries of a cathedral church, the conversation turning on the riots in Birmingham, and on a clergyman having said that if Dr. Priestley were mounted on a pile of his publications he would set fire to them and burn him alive, they all declared that they would be ready to do the same. Dr. Priestley had been a friend of Edmund Burke, who wrote a furious book against the French. This was replied to by Priestley so ably that the orator was greatly exasperated and inveighed against his friend's character repeatedly in the House of Commons. Dr. Priestley denied his charges, and called on him for proof again and again, but he made no reply, whereupon the doctor published that Burke "had neither ability to maintain his charge nor virtue to retract it." Dr. Priestley was informed, by a person who was boarding at the same house with Burke at Margate when the riots broke out at Birmingham, "that he could not contain his joy, but, running from place to place, he expressed it in the most unequivocal manner."

The prolonged persecution to which Priestley was subjected after the riots, and the extent and virulence of the feeling against him, show that the affair was something more than the mere outbreak of the Birmingham mob, and the course taken by government sufficiently attests that the riotous populace were but the tools of their superiors. While the country in general evidently exulted in his sufferings, the representatives of the nation refused to inquire into the cause of them. The courts delayed to give him the damages to which he was entitled, and their award fell $10,000 short of his real loss. As an illustration of the spirit which ruled the dispensation of justice, it may be mentioned that the manuscript of a work on the Constitution of England, as large as "Blackstone's Commentaries," was destroyed, and Priestley's own lawyer advised him not to make a claim for it, because it would be ruled as a seditious work and aggravate his case. Accordingly, this manu-

script, in the schedule of losses, was simply put down as so much paper.

To the charge that he was a promoter of sedition, Dr. Priestley replied by appealing to his entire intellectual career, into which politics had hardly entered at all, from his complete engrossment with other subjects. In relation to this he says: "As to the great odium that I have incurred, the charge of sedition, or my being an enemy to the constitution or peace of my country, is a mere pretense for it, though it has been so much urged that it is now generally believed, and all attempts to undeceive the public with respect to it avail nothing at all. The whole course of my studies from early life shows how little politics of any kind have been my object. Indeed, to have written so much as I have in theology, and to have done so much in experimental philosophy, and at the same time to have had my mind occupied, as it is supposed to have been, with factious politics, I must have had faculties more than human. Let any person only cast his eye over the long list of my publications, and he will see that they relate almost wholly to theology, philosophy, or general literature."

In regard to the religious aspect of the case, he observes: "It might have been thought that, having written so much in defense of revelation, and of Christianity in general, more, perhaps, than all the clergy of the Church of England now living, this defense of a *common cause* would have been received as some atonement for my demerits in writing against civil establishments of Christianity, and particular doctrines. But, had I been an open enemy of all religion, the animosity against me could not have been greater than it is. Neither Mr. Hume nor Mr. Gibbon was a thousandth part so obnoxious to the clergy as I am; so little respect have my enemies for Christianity itself, compared with what they have for their emoluments from it."

It was the obvious tendency, as it was the undoubted design, of the systematic persecution to which Dr. Priestley was subjected, to drive him from the country. His sons, disgusted with their father's treatment, had renounced England and gone over to France; and it was expected that Dr. Priestley would follow them. He was not at first disposed to comply with the general expectation, and stated that he should not be driven away; but upon the breaking out of the war between France and England his sons emigrated to America, and this circumstance, joined to the state of isolation in which he lived, induced Dr. Priestley after much deliberation to decide upon following them. Intolerance and bigotry were thus triumphant; and the greatest scientific discoverer of his century, whose labors will reflect imperishable glory upon England, instead of receiving the honors that were due him, was hunted out of that country and driven into exile like a common felon.

Dr. Priestley sailed from London in April, 1794, and arrived in New York in June. He was received there by various societies with

distinguished consideration, and a hundred subscribers, at ten dollars each, were immediately secured for a course of lectures on Experimental Philosophy. He did not, however, give them, but shortly proceeded to Philadelphia, where he received a complimentary address from the American Philosophical Society, and was unanimously chosen as Professor of Chemistry in the university. But this he did not accept, and soon proceeded to Northumberland, a town on the Susquehanna, 132 miles northwest from Philadelphia, where his sons had settled, and which he made his permanent residence. There was at first no postal connection with the place, but a mail was soon established, running to Philadelphia twice a week. His house in Northumberland was situated in a garden commanding one of the finest prospects on the Susquehanna. A library and laboratory were built for him, which were finished in 1797, and he was able to arrange his books and renew his experiments with every possible facility.

While Dr. Priestley was received in this country by many with the honor that was due to so eminent a man and the sympathy to which his persecutions at home naturally gave rise, it was not to be expected that he would quite escape from the interference of the intolant and narrow-minded. There was, at that time, a powerful party in this country in sympathy with the English policy, and they very naturally participated in the English feeling toward Priestley. He did not choose to be naturalized, but, while advising his sons to become so, he said that, as he had been born and had lived to advanced years an Englishman, he would die one, let what might be the consequence. He did not interest himself much in American politics, but continued his congenial pursuits and studies. About the year 1799, during the Adams Administration, the friends of freedom were greatly alarmed at the promulgation of principles less liberal in many respects than were those of the British Government. Dr. Priestley, who never concealed his sentiments, was opposed to the administration and freely criticised it in private conversation. At the same time, violent attacks were made upon it by a Northumberland newspaper. But, although Dr. Priestley was not their author, and had nothing to do with them, they were charged to him, and such were the bigotry and party zeal of the period that he was represented as an enemy to the Government, and it was intimated to him from Mr. Adams himself that he had better abstain from saying any thing on politics lest he should get into difficulty. The "Alien and Sedition Law" passed under that administration was then in operation, and Dr. Priestley might have been sent out of the country at a moment's warning, without being charged with any offense and without even the right of remonstrance; and it was hinted to him that he was one of the persons contemplated when the law was passed. The epithet *alien*, which was used as a term of party reproach at that time, was freely applied to him. In consequence of all this, Dr. Priestley wrote a

series of letters to the inhabitants of Northumberland, in which he expressed his sentiments fully on all political questions, and which had the effect of removing unfavorable impressions which had been made on the minds of the people.

It is important to state, in illustration of Dr. Priestley's principles and character, that he believed most thoroughly in the efficacy of private enterprise for carrying on all works of popular beneficence. A powerful opponent of state-enforced religion, he was led to go much further and to condemn government patronage in numerous other cases. And this was very far from being a matter of sour grapes, or a repudiation of advantages, because he could not himself participate in them. On the contrary, he had the most brilliant and tempting opportunities. His residence and intimacy with Lord Shelburne brought within his reach the largest prospects of political and ecclesiastical preferment, both of which he resolutely declined. Under two different administrations, overtures were made to him to accept a pension from Government; but he stands conspicuously alone in his age in resisting the temptation and preserving his independence. He, however, accepted assistance from private generosity, and was always grateful for donations from this source. As an illustration of how he continued to be appreciated in England after leaving it, it should be stated that Mrs. Elizabeth Rayner allowed him a pension of $250 a year, and in her will left him $10,000. Mr. Dodson left him $2,000; Mr. Salte, $500; and the Duke of Grafton remitted him annually $200. About the time he died, a few other friends made up $1,000 a year, which was quickly increased to $2,500, which was to have been continued during his life. These contributions were made in consideration of the heavy expense of his experimental researches, and the printing of his Church history and other theological works. These examples of generous appreciation were peculiarly grateful to Dr. Priestley, after the treatment he had received at home.

In 1801 Dr. Priestley had a severe illness in Philadelphia, and, after that, never fully recovered his strength. He was subject to attacks of inflammation of the stomach and paralysis of the throat, which prevented swallowing. In January, 1804, his complaint grew so serious that life began to be doubtful, and he used to tell the physician that, if he could but patch him up for six months longer, he should be perfectly satisfied, as by that time he could complete the printing of his works. This, however, was not granted, for he died on the 6th of February, seventy years ago, after working to almost the last hour. His old congregation, at Birmingham, erected a monument to his memory in their place of worship after his decease, and a fine marble statue has been recently put up in his honor in the University of Oxford. The accompanying engraving is from a portrait by the celebrated painter Gilbert Stuart.

It remains to add, that Dr. Priestley was eminently fortunate in

his domestic relations. His wife possessed rare qualifications, as a helpmeet to her husband, and had a large share in the success of his career; for, although, as far as we can learn, she did not participate in his special studies, yet it appears that, but for her, he never could have carried through his numerous and formidable undertakings. His testimony to this is explicit. He says: "My wife was a woman of excellent understanding, much improved by reading, of great fortitude and strength of mind, of a temper in the highest degree affectionate and generous, feeling strongly for others and little for herself. Also, greatly excelling in every thing relating to household affairs, she entirely relieved me of all concern of that kind, which allowed me to give all my time to the prosecution of my studies, and the other duties of my station." His son states that his father used to say that he was merely a lodger, and had all his time to devote to his own pursuits.

All honor, then, to the wife to whose womanly devotion the world is indebted for whatever is great and good in the achievements of the husband! We have lately heard much of a great man who attributes all his profoundest thoughts to the genius of his wife, he being really only a scribe and editor; but we here see how a great man may owe his intellectual eminence to his wife, even though she be not so gifted as to be able to furnish all his best ideas. Of the two methods, this is certainly the most encouraging for woman, as it assigns the highest office to her acknowledged capacities, and precludes all question of rivalry. The united pair work in separate spheres and different ways to the same end; and the wife's affections become as indispensable to the result as the husband's intellect. Had Mrs. Priestley been animated by modern views, and essayed to carve out her own separate fortune in the field of science or theology, it is eminently probable that she would have failed to do any great thing herself, and quite certain that she would have effectually defeated her husband. This must have been the result, if what Dr. Priestley says is true, that her efficient domestic aid and her sympathetic support in his trials and sufferings were among the indispensable conditions of his own success. And thus, in the seclusion of her own family, absorbed in social cares, forgetting herself in instinctive solicitude for others, and probably with no ambition beyond, this true woman and model wife was really joint-partner with her illustrious husband in the good he accomplished, if not in the fame he won. And who shall say that hers was not, after all, the nobler and happier share of the work?

EDITOR'S TABLE.

THE CENTENNIAL ANNIVERSARY OF THE DISCOVERY OF OXYGEN.

ON the 1st of August, 1874, it will be exactly a hundred years since oxygen gas was first made known to the world. This discovery is one of the most important ever made in science, and we commemorate its centennial by doing something to make more widely known the character of the illustrious man whose name will be associated with it as long as science is cultivated or civilization continues.

A hundred years of advancing knowledge has steadily exalted the importance of Priestley's discovery. It formed a great epoch in the progress of modern chemistry, and gave a profound clew to the internal constitution of Nature. The element first revealed, examined, and described by Priestley, is the most extensive in its distribution, and the most potent in its influence, of all the material constituents of the world. We now know with some definiteness the proportions in which oxygen exists in the various parts of Nature, but the aggregates are so stupendous as utterly to baffle the imagination. It exists in the smallest proportion in the atmosphere, forming but one-fifth of its weight. As there are fifteen pounds weight of air on every square inch of the earth's surface, it follows that there are three pounds of oxygen to the same area. By a simple calculation, it therefore turns out that the amount of oxygen in the earth's atmosphere is one quintillion, one hundred and seventy-eight quadrillions, one hundred and fifty-eight trillions of tons—a quantity absolutely inconceivable by the human mind.

In the world of waters, the scale of proportions is enormously increased, as eight-ninths of the weight of this liquid consists of oxygen. The ocean is assumed to cover two-thirds of the earth's surface, and to have an average depth of two miles, which would be sufficient to cover its entire surface to the depth of one mile and one-third. This would give us twenty-seven hundred pounds of oxygen for every square inch of the earth, or an amount in the oceans equal to nine hundred atmospheres.

Chemical analysis has also shown us the proportions of oxygen in the various classes of rocks. It forms one-half the weight of silica, one-third that of alumina, and two-thirds that of lime; and, as the great bulk of the geological formations are made up of these minerals, it follows that the entire crust of the globe, so far as it has been explored, with its twenty miles' thickness of stratified rocks and its underlying granites, consists of oxygen to the extent of one-half of its weight.

If we turn now to the world of life, although the absolute magnitudes are much less, the relative proportions of oxygen are very high, and the grandeur of its operations is simply amazing. Three-fourths the weight of the entire animal world, and four-fifths the weight of the whole vegetable kingdom, consist of this element alone. Moreover, the operations of life in both branches are intimately dependent upon its activity and the rapid changes of which it is the main agent; while the vegetable kingdom is a grand laboratory, worked by the power of the solar rays to liberate oxygen from its combinations, and pour it back into the atmosphere in a free and active state. The animal kingdom, on the other hand, through all its grades, depends for its existence upon the incessant withdrawal of oxygen from the air. Each adult

person consumes two pounds a day of this gas, or over seven hundred pounds a year, or some twenty-five tons in the allotted period of seventy years; and the thousand million human beings upon the earth are all busy, day and night, from birth to death, in altering the constitution of the air at the same rapid rate. And what man is doing, all the multitudinous tribes of inferior life, in the sea, on the land, and in the air, are doing also. Besides this, the great operations of combustion, fermentation, and decay, upon the globe, are carried on by the insatiable affinities of the same ubiquitous agent. It has been calculated that the oxygen required daily to maintain the course of terrestrial transformations is no less than eight thousand million pounds, or seven millions one hundred forty-two thousand eight hundred and forty-seven tons.[1] And, though this is probably an extreme under-estimate, we have seen that the stock of free oxygen in the air is so vast that it would require millions of years for this rate of consumption to make a sensible impression upon it, even if the counter-changes of the vegetable kingdom, by which the balance is constantly restored, should altogether cease.

Such is the grandeur of the part played by this wonderful element of Nature which has now been known exactly a hundred years. In his beautiful lecture which forms the opening article of our present number, Dr. Draper has vividly portrayed the office of oxygen in relation to the scheme of terrestrial life, and to this nothing needs to be added. But it is fit, on the present occasion, to give emphasis to the fact that, up to the time of Priestley, mankind were as absolutely ignorant of these things as if they had been destitute of all capacity to understand them. The human race had indeed run a vast career of intellectual activity, and had exploited numberless fields of thought with great results. Forms of religion and systems of philosophy had grown and decayed; numerous arts were perfected and forgotten; literatures were cultivated, exhausted, and passed by; empires and civilizations had flourished and faded, and for many thousands of years the world's greatest minds had been speculating, questioning, and inventing, before the man appeared who first explained the constitution of the air, and who first gave a rational answer to the question, "What is the breath of life?" At a superficial glance we should infer that there had been an enormous waste of precious intellectual force in all those historic ages over futile and worthless subjects, and that, while investigating with infinite assiduity every thing that was remote and impossible, the vital and immediate matters of daily and intimate concern had been systematically shunned as objects of study. But the intellectual evolution of man has conformed to a method, and Nature seems to have been no more economical of her mental than of her material resources. There is a prodigality in her ways which a narrow philosophy cannot comprehend. Of her profusion of flowers, but few issue in fruit; of her myriads of eggs, but few are hatched; of her numerous tribes of life appearing in the remote past, multitudes are extinct; and, of the achievements of her intellect, the great mass is lost in oblivion. But, through all her seeming waste, Nature has, nevertheless, a grand economy. She gives the widest chances, under a system which favors the best; the failures are rejected and the fittest survive. Through apparently boundless waste, with infinite deliberation, she works onward and upward to a better state of things, and in the mental world no less than in the physical, through interminable defeats and failures, and a prodigious amount of empty and fruitless effort, solid and

[1] The foregoing data are taken from Faraday's "Lectures on the Non-metallic Elements." London: Longmans, 1853.

permanent results are at last arrived at. Modern science arose from the exhaustion of previous methods of thought. The earlier philosophy speculated concerning Nature, and sought after her truths in the depths of the human mind. All that high genius and varied intellectual power could do was done, but to no purpose until the searchers for truth changed their attitude to Nature, and began to inquire of her by the simple and despised methods of experimental investigation. Dr. Priestley, first of all men, approached the problem of the constitution of the air in this spirit, and was even compelled to devise the contrivances by which gaseous bodies could be manipulated. He was on the right track, he had struck the true method, and magnificently did Nature reward his sagacity and his wisdom. Of course, for the Greeks or the Romans, or the schoolmen of the middle ages, to have discovered oxygen, would have been impossible. Only with the decline of their modes of thought could new methods arise, and only through the apprenticeship of generations in the field of physical investigation were men prepared to pass to the subtler search of the inner nature of material things. The discovery of oxygen, therefore, came in its due time in the mental unfolding of humanity; and while to Dr. Priestley undoubtedly belongs the honor of having first disclosed and identified it, others would quickly have plucked the ripened fruit if he had not; and in point of fact oxygen was independently discovered shortly after by the Swedish chemist Scheele, who also discovered chlorine in 1774.

But, if the discovery of oxygen formed a great epoch in our advancing knowledge of the constitution of Nature, its influence was no less profound upon the advance of chemical science. We are accustomed to regard chemistry as a kind of knowledge that is peculiarly modern, but it is really very old, and has had a long course of development. Liebig has stated that the completion of a science implies three stages or operations. There are—1. The ascertainment of the properties of things by observation and experiment; 2. The bringing of them into relation by principles or ideas; and, 3. The application of mathematics, or subjecting the phenomena to the test of quantitative investigation. In chemistry, the first of these stages runs back to antiquity. The ancients knew many facts and made many empirical experiments in the arts which were of a chemical nature. They knew seven metals—gold, silver, mercury, copper, iron, tin, and lead. They also knew various preparations of zinc, antimony, and arsenic, and must have had a very considerable knowledge of metallurgical processes. They had also a knowledge of glass, pottery, soap, dyes, pigments, precious stones, asphalt, alum, starch, beer, and many other substances which, if not exact, was still so positive as to guide them in the processes of manufacture. This kind of knowledge of the properties of bodies must have gradually increased, and when we come down to the time of Gheber, the Arabian, who wrote a thousand years ago, we find that this species of information had not only greatly increased, but had become more definitely chemical in character, while laboratory operations were systematically practised. Gheber, for example, knew the properties of common salt, potash, soda, saltpetre, ammonia, copperas, borax, corrosive sublimate, oxide of copper, metallic arsenic, compounds of sulphur with the metals, and the methods of preparing sulphuric and nitric acids, aqua-regia, litharge, and the operations of distillation, sublimation, smelting, and a great number of chemical processes, as they were practised down to the end of the eighteenth century. By the alchemists these facts were immensely multiplied, forming a vast body of knowledge concerning the chemical proper-

ties of substances which form the foundation of the science, and constitute Liebig's first stage in its progress.

Although the second stage — the formation of general ideas or theories —is a sequence of the first, and implies accumulated observations to be explained, yet it was begun early. The doctrine of the four primitive elements, fire, air, earth, and water, was the first chemical theory, and sufficed for many centuries. To these four elements of Aristotle, which were regarded as the four fundamental causes of the physical properties of matter, were added three new elements—mercury, sulphur, and salt—which also stood for certain properties and causes of change, rather than concrete bodies. Mercury represented volatility, and was supposed to give this property to matter; sulphur was connected with changeableness by fire, or combustibility, and salt represented fixity, like the salts found in ashes. On this view, alcohol, or aqua vitæ, was regarded as "sulphurous vegetable mercury," which only meant that it was inflammable and volatile. Hence Basil Valentine says: "When a rectified aqua vitæ is kindled, its mercury and sulphur separate; the sulphur burns quite vividly, for it is pure fire, and the delicate mercury flies into the air and returns to its original chaos."

Such rude ideas answered to begin the work of chemical theorizing, but the increase of facts at length showed that they were contradictory and absurd. About a hundred years before the time of Priestley, Beecher, a German chemist, in undertaking to correct the doctrine of salt, sulphur and mercury, struck a new conception which soon grew into a comprehensive and important chemical theory. In working with sulphur, he sagaciously detected the analogy between the formation of sulphuric acid from sulphur and the reduction of metals to an earthy form (calx). The metal was supposed to consist of an earth, and something which, in the process of combustion, was separated from it; in like manner sulphur was supposed to consist of an acid and something that was separated from it, by burning, and to this something Stahl afterward gave the name of *phlogiston*—Greek for *combustible*. So intimately and extensively were fire and combustion involved with chemical changes, that a theory of combustion was regarded as the same thing as a theory of chemistry. It was assumed that all combustible bodies are compounds. One of the constituents was supposed to be dissipated during the process, while the other remained behind. The part dissipated, phlogiston, was held to be the same in all combustible bodies whatever, and hence the differences among them depended upon the residues. On this view, the property of combustibility is always owing to the presence of phlogiston, and fire, or inflammation, to its escape. Phlogiston was communicable from body to body. When phosphorus is burned it loses its phlogiston, and an acid remains. But if now the acid is heated in a retort with charcoal-powder, sugar, or resin, these combustibles are deprived of their phlogiston, which, passing over to the acid, reproduces phosphorus. Bodies saturated with phlogiston were said to be *phlogisticated*, and, when deprived of it, were *dephlogisticated*, processes which might be as partial or complete as the variations of combustive phenomena. These ideas were founded upon experiments so decisive that, when the existence of the principle itself was once admitted, the explanation was entirely satisfactory. "There are ideas," says Liebig, "so great and vast that, even when entirely perforated, as it were, in all directions, they leave enough of matter to occupy the powers of thought of mankind for a century. Such a vast idea was that of phlogiston. The question as to its material existence was void of

all significance, so long as the idea was fruitful in the classification of known facts, and prepared the way for new generalizations."

Chemistry had made rapid advances under the phlogistic theory for a century, but the idea was now to be brought to the test of quantitative examination. The introduction of the balance threw a new light upon the subject, and, under its application, the assumptions of the phlogistic system of chemistry proved to be entirely erroneous. The effect of careful weighing was to show that metals and other combustible bodies, in burning, grew heavier; that there was no subtraction or loss of any thing, but always an addition; and that the compounds produced were, in every case, equal in weight to the combining elements.

Dr. Priestley was a firm believer in phlogiston, and named the new element of the atmosphere which he had discovered, dephlogisticated air. He made but little use of weighing in his researches, and was not qualified by his training to go on and reap the full scientific advantages to which his great discovery opened the way. These were secured by the French chemist Lavoisier, who named the new element oxygen, and, having by his experiments overthrown the old view, he had the largest share in establishing the oxygen theory of chemistry which took its place. As Dr. Whewell observes; "Few revolutions in science have immediately excited so much general notice as the introduction of the theory of oxygen. The simplicity and symmetry of the modes of combination which it assumed, and, above all, the construction and universal adoption of a nomenclature which applied to all substances, and which seemed to reveal their inmost constitution by their name, naturally gave it an almost irresistible sway over men's minds."

But, while the theory of oxygen has guided the development of chemistry for the past hundred years, it is now following the fate of its predecessor: the facts have outgrown it, and a "New Chemistry" has arisen in its place. Yet, whatever may be the vicissitudes of theory, oxygen is still in the field—still the object of wonderful interest, and no possible changes in the future can ever dim the lustre of its discovery.

CHARACTER OF DR. PRIESTLEY.

Several of the most distinguished chemists of the country have united in a call to all interested to convene at Northumberland, Pa., on the 1st of August, where Dr. Priestley lies entombed, to celebrate the one hundredth anniversary of his discovery of oxygen gas. Such a tribute will be most proper and befitting to his memory, and will suggest interesting phases of thought that cannot fail to make the occasion profitable to all who participate in it. In the circular of invitation it is said: "The fact that this illustrious man spent the last years of his fruitful life in this country, renders the recognition of his work by American chemists peculiarly appropriate;" and it may be added that the circumstances which brought him here, and which pertain both to his own character and the condition of his native country, are matters especially suitable for consideration at such a time. For Dr. Priestley was more than an eminent scientific discoverer — he was a sincere, courageous, high-minded man, and stood forth as the unflinching champion of liberal opinion when his country was given over to the narrow spirit of fanatical bigotry. Dr. Priestley's career exhibits the sublime moral spectacle of a man against a nation, and that, too, on a vital question of constitutional rights; and such was the conduct of the two parties, as, in the language of Dr. Thomson, to "fix an indelible disgrace upon the country," while Dr. Priestley's course will

be honored as long as freedom of opinion and independence of character elicit the admiration of men.

Dr. Priestley's intellectual greatness is the more remarkable as he led what may be called a divided life. He was a discoverer in science, and a pioneer in theology. His extensions of our knowledge of Nature will suffice for his immortality, while the extent and power of his theological work made him famous among his contemporaries. Nevertheless it is only by concentration that the highest results can be achieved. We have shown in the preceding article where Dr. Priestley fell short as a man of science. His scientific education was insufficient. He began these studies late, and pursued them at great disadvantage, for scientific pursuits are expensive. He says: "I applied myself with great assiduity to my studies, which were classical, mathematical, and theological. These required but few books. As to experimental philosophy, I had always cultivated an acquaintance with it, but I had not the means of prosecuting it." His great rival, Lavoisier, was more fortunate. His father was rich, and spared no expense on his education; and, having an early taste for the physical sciences, he was trained to experimental research, which he pursued so successfully that, at twenty-one, he received a gold medal for a memoir on the best and most economical method of lighting the streets of a large city. Could Priestley have had similar early advantages, there is little doubt that he would have devoted himself entirely to science, and, with his remarkable genius for investigation, would have impressed himself far more profoundly upon the chemistry of his period.

Of the truth or error of Dr. Priestley's religious opinions, it is no place here to speak; but, that he sought the truth in all earnestness, and maintained what he believed to be the truth with steadfast determination, does not now admit of question. That he led a life of the highest purity was never doubted, even by his enemies, and that he was ever animated by a high religious aspiration his works bear abundant witness. A portion of each day was given to prayer and private devotional exercises, and he kept up the practice of Sunday preaching, whether officially engaged or not; while the uniform testimony of all his parishioners showed that his ministrations were conducted in a loving, Christian spirit. Shall we question that the religious experience of such a man was not profound and genuine? And yet he was a speculative materialist; that is, he did not believe in "the immateriality of the sentient principle in man." No one, however, had a firmer belief in immortality and the future life than Dr. Priestley. This transcendent article of his faith he did not ask at the hands of Science nor hold as dependent upon her investigations. His repose in the prospect of immortality was grounded on the Christian doctrine of a resurrection; no results of science could reach or disturb it, and in this he was far in advance, not only of his own age, but of ours. As an illustration of his independence of character, and his scorn of all temporizing, it may be stated that he promulgated these views while living under the patronage of Lord Shelburne, and beset with solicitations to accept high favors from the Church and the state. Undoubtedly, as Dr. Draper remarks, it is upon his discoveries that his future fame will rest, while his theological works are already forgotten; yet the world owes him a debt for his manly maintenance of independent inquiry in a cowardly age and among a craven people, which will command respect as long as the nobler virtues of character continue to be appreciated.

SCIENTIFIC APPARATUS.

THE attention of those desiring to procure physical-science apparatus is called to the advertisement of Profess-

or W. C. Richards, Ph. D., who, having retired from the public lecture-field, offers for sale his extensive collection of instruments. The stock includes duplicates of important pieces, such as coils, batteries, spectroscopes, vacuum-tubes; and it offers an excellent chance for colleges, high-schools, and private students, to supply themselves from this collection. Those who are in want of such instruments should send to Professor Richards for his catalogue.

LITERARY NOTICES.

SMITHSONIAN MISCELLANEOUS COLLECTIONS; THE CONSTANTS OF NATURE. Part I. Specific Gravities; Boiling and Melting Points; and Chemical Formula. Compiled by FRANK WIGGLESWORTH CLARKE, S. B. Washington, D. C., 1873.

THIS volume of 263 pages is No. 255 of the publications of the Smithsonian Institution, and it is yet another evidence of the care and thought bestowed by the venerable Secretary of that Institution upon all means and aids suitable for the advancement of human knowledge.

It is Part I. of a series which is to contain the Constants of Nature, tabulated in such a way as to be immediately available for the uses of scientific men, as well as for general reference.

A careful examination of its general plan shows that this work has been admirably done by Prof. Clarke (now of Howard University, Washington). The work can be consulted with great convenience by means of the very complete Index, and on turning to any page the information is found in five columns side by side. The first column contains the name of the substance, as, for example, *Iodine;* in this column also the letter *l* or *s* shows that the substance has been examined in a *liquid* or a *solid* state.

The third column contains the specific-gravity determinations which have been made, accompanied by figures showing the temperature at which they were made, and a reference number to each line indicates the authority (volume and page usually) from which the datum is selected. Another symbol in this column, "*m.* of 6," for example, shows that the determination was the *mean of six* determinations.

The next column gives the boiling-point in degrees Fahrenheit, together with the height of the barometer at which this element was determined, and the fifth column gives the melting-point.

Sulphur has thirty-two lines devoted to its properties; *Tin* has eighteen; *Bismuth* eighteen, etc.

As an example, we extract line No. 7 of *Sulphuric Acid.* The No. 7 refers us to a paper by H. L. Buff in the "Annals of Chemistry and Pharmacy," fourth supplement (1865–'66), p. 129, and also to various articles quoted in that paper. The line reads: "Sulphuric Acid; SO 3; 1.81958, 47°; 46° to 47° 760 m.m.; rs. 25°;" which shows that the specific gravity was determined at 47° Fahr. to be 1.81958, that at 760 m.m., the boiling-point was from 46° to 47° Fahr., and that this specimen resolidified at 25° Fahr.

It only remains to add from Prof. Clarke's modest preface, that the work, "exclusive of its supplement, contains the specific gravities of 2,263 substances, and over 5,000 determinations in all. There are over 2,000 determinations of boiling-point, representing 1,205 different substances; and nearly 500 of melting-point for 326 different substances. In all, the names of 2,572 distinct bodies will be found in the table."

PHYSIOLOGY FOR PRACTICAL USE. Edited by JAMES HINTON. With Introduction by E. L. YOUMANS. New York: D. Appleton & Co., pp. 507. Price $2.25.

Too few books have honest titles, for these are as often chosen to mislead as to instruct. The present is among those that are accurately described by their names. For, while there is a great deal of interesting scientific physiology in this volume, its distinctive character is that it furnishes physiological knowledge that can be continually applied to practical use. Dr. Hinton, the editor, is an eminent aural surgeon of London, and contributes the article to this volume on "The Faculty of Hearing." We published a portion of that article some time ago in the MONTHLY, and all who read it will attest that it was one of the best practical presentations of the subject that has yet ap-

peared. The other chapters of the volume are contributed by other medical men, who have given special attention to different departments of practical physiology; and the ruling idea of all the articles is to give in the clearest and plainest manner that information concerning the bodily organs and their management which is most constantly needed, and which all common readers can understand and apply. The papers of the volume were first contributed to the *People's Magazine* in monthly parts, running through two or three years; they were then collected and carefully revised by Dr. Hinton, and brought into the unity and completeness which they now present, in the volume form.

In several respects this book presents universal claims upon the reading public. To begin with, the style in which it is written is remarkable for its simplicity, its freedom from technical terms, and its extreme *readableness*. The writers seem to have constantly kept in mind that they were addressing the non-scientific public, and they have studiously refrained from any pedantic show of physiological language. There is not a chapter in the volume that any ordinary person cannot take up and peruse with facility and pleasure. The importance of this cannot be over-estimated where the object is to produce clear and lasting impressions upon the general mind.

In the next place, the selection of the subjects treated is as practical as the manner of their statement. How completely the whole ground is covered may be shown in no other way so well as by an enumeration of the subjects, which are as follows:

I. The Brain and its Servants.
II. The Faculty of Hearing.
III. The Eye and Sight.
IV. The Sense of Smell.
V. The Sense of Taste.
VI. Digestion.
VII. The Skin.—Corpulence.
VIII. The Bath.—The Sense of Touch.
IX. Notes on Pain.
X. Respiration.
XI. Taking Cold.
XII. Influenza.
XIII. Headache.
XIV. Sleep.
XV. Sleeplessness.
XVI. Ventilation.
XVII. The Liver and its Diseases.
XVIII. The Action of Alcohol.
XIX. Muscular Motion as exemplified in the Human Body.
XX. Occupation and Health.
XXI. Training and Gymnastics.

In the third place, on all of these subjects it has been the aim of the writers to present that kind of information which can be made practically available for the preservation of health. There is only so much scientific physiology as is calculated to give point and effect to the useful inculcations of the work. It is the best popular hygienic treatise that we know, and is the kind of book to tell in a salutary way upon the daily conduct. It is here that our physiological text-books generally break down. The information they contain is of the wrong kind—too scientific and too unpractical. There is a good deal of excellent science in this volume, clear and accurate in its presentation; but it is all subordinated to the useful lessons and conclusions that are enforced in regard to what may be called physiological conduct and practice. Such a volume has been long wanted, and we commend it for family reading and for class-exercises in schools, as superior to any other we know.

THE AMERICAN ANNUAL CYCLOPÆDIA AND REGISTER OF IMPORTANT EVENTS OF THE YEAR 1873. Embracing Political, Civil, Military, and Social Affairs; Public Documents; Biography, Statistics, Commerce, Finance, Literature, Science, Agriculture, and Mechanical Industry. Volume XIII. New York: D. Appleton & Co., 1874, pp. 805. Price, $5.00.

THIS work, which is extended to thirteen volumes, forms the completest history of contemporaneous events that is now to be obtained. Year-books of science, agriculture, inventions, and arts, have latterly appeared, in response to the demand for the results of the annual progress in these departments. But something more comprehensive was needed, that should treat of what is done in all the great branches of activity. Appletons' Annual Cyclopædia is perhaps the most perfect register of the advance of civilization that we have—covering the complete ground, carefully compiled, conveniently arranged

for consultation, and constituting a full repertory of passing occurrences. It is indispensable to the student of current affairs, and should have a place in the library of every working thinker. Appletons' Annual Cyclopædia is a work entirely distinct from their regular American Cyclopædia, which is of a more general character, and treats of the past as well as of the present.

The volume just issued contains the annals of the past year. Its wars and military operations are faithfully described. The internal commotions of states also receive due attention, and the student of foreign politics will peruse, with keen interest, the succinct account here given of the civic strifes of France and Germany, and the sanguinary conflict still going on in Spain. The chronicle of home events is very full. The questions which occupied the minds of our legislators during the year, and which have in any way affected the prosperity of the country, are faithfully presented. Thus we have articles on the national finances, revenue, and taxation; banking, financial crises, commerce, manufactures, etc. The financial condition of the several States also receives attention. In short, no great public concernment is overlooked, and, to give an exact idea of what this volume contains, we should have to enumerate every living practical interest of our people—the movements of political parties, the transportation question, the granger question, the results of elections, proceedings of legislative bodies, judicial decisions, the progress of educational and charitable institutions, the extension of railroads and telegraphs, etc. The diplomatic correspondence of the United States Government, derived from authentic sources, is presented with great fullness. The progress of science, in various branches, is recorded; special prominence being given to the practical applications of scientific discoveries, and, finally, we have the authentic statistics of religious denominations in the United States.

Smithsonian Report for 1872.—The Smithsonian Institution closed the first quarter of a century of its existence with the year for which this report was made. During that time it has made itself known in every part of the civilized world, and "the publications which result from the facilities it has afforded to original research are to be found in all the principal libraries, and its specimens in all the great public museums in the world."

The report of the Secretary, Prof. Henry, evidences admirable management in the financial affairs of the Institution. The original fund, instead of being impaired, has been increased. It now amounts to $704,811; the income from which, during the year 1872, amounted to $46,916. The expenditures for the same time were $45,420. However, this good management has not always existed. Prof. Henry shows that in the establishment of the Institution, the United States Government, through a misconception of the object of the founder, expended $600,000 in the erection of buildings, while the object could have been attained by an outlay for the same purpose of only $50,000. The object of the founder appears to have been the establishment of an institution for the promotion of original scientific research, and the distribution of the knowledge thereby gained; while the Government construed it to be the establishment of a museum, library, art-gallery, lectorium, arboretum, etc. Prof. Henry now suggests that the Government should devote the present building to the use of the National Museum, and repay the Smithsonian fund $300,000; one-third of which could be used for the erection of another building suitable to the Institution, and the remainder be added to the present fund.

The most important work of the Institution consists in the publication of contributions to knowledge, or scientific papers, containing positive additions to knowledge, papers which are the results of investigations directly or indirectly fostered by the Institution, or of individual investigations, but are too expensive in character to be otherwise published. Also, the publication of miscellaneous collections intended to facilitate the study of particular branches of science. These publications are distributed with various specimens, ethnological and otherwise, to libraries and museums throughout this and foreign countries. The most important works published or prepared for publication by the Institution, in 1872, were "Tables and Results of Precipitation of

Rain and Snow in the United States and Adjacent Parts of North, Central, and South America;" "Work on the *Fresh-Water Algæ*," by Dr. Horatio C. Wood, of Philadelphia; and Prof. Newcombe's "Investigations into the Orbit of Uranus." The Institution has also in preparation "Vocabularies of the Indian Languages of North America;" a "Hypsometrical Map of North America;" and the "Meteorological Observations" of the Institution up to 1870.

The report also contains the late Prof. Agassiz's "Narrative of his Expedition from Boston through the Straits of Magellan to San Francisco," and a number of valuable papers by foreign authorities on various scientific subjects, published because of their inaccessibility to students generally.

THE CONSTRUCTION OF MILL-DAMS. Springfield, Ohio: James Leffel & Co. 312 pp., 8vo. Price, $2.50.

THIS is a republication in book-form of a series of articles first published in Leffel's *Milling and Mechanical News*. It advances no new theory on the subject, but presents a description of various plans that have been tried and found effective in different localities. The work is more descriptive than scientific in character, but it contains some apparently valuable suggestions on the building of small and economical dams, such as are required for a single grain or lumber mill. Descriptions are given of the Housatonic Dam, in Connecticut, the Moline Dam, on the Mississippi, and other remarkable dams. A simple and seemingly sufficient method is given for determining the available power of small streams. The work is admirably illustrated throughout.

THEORY OF THE GLACIERS OF SAVOY. By M. Le Chanoine RENDU. Translated by ALFRED WILLS. With Additions by TAIT, RUSKIN, and FORBES. London: Macmillan, 1874. Price, $3.00.

THIS is a work of some historic interest, being one of the earliest contributions to the elucidation of glacial phenomena. The merit of Rendu, as a pioneer explorer in this field, is now generally recognized; and whatever of truth there was in his views has been absorbed into the common literature of the subject. Nevertheless, it is well to have his valuable book in an accessible form. But we are afraid that its intrinsic interest would have been insufficient to secure its translation, and that the reason of its appearance at the present time is to be sought elsewhere. The train of names upon the title-page gives a clew to the purpose for which it is now reproduced. A clique of Scotchmen, in getting up a biography of Principal Forbes, has contrived to get into a quarrel with Tyndall, in regard to the allotment of the honors of discovery, and Rendu's book is now used as a means of bespattering the Royal Institution professor. We publish Prof. Tyndall's review of the work, and readers who wish to go deeper into the matter can consult the book itself.

BULLETIN OF THE BUFFALO SOCIETY OF NATURAL SCIENCES.

THE last number of the *Bulletin* is full of interesting matter. It contains, besides other entomological contributions, several papers on the study of butterflies, by A. K. Grote, Samuel H. Scudder, and others. In "Contributions to the Geology and Physical Geography of the Lower Amazons," Prof. C. Frederick Hartt gives some valuable information on the topographical features, drainage, and geological formation of the Ereré-Monte-Alegre district of South America. The number is embellished with numerous fine plates.

ANATOMY OF THE INVERTEBRATA. By C. T. H. v. SIEBOLD. Translated from the German, with Additions and Notes, by WALDO I. BURNETT, M. D. Boston: James Campbell, 1874. 8vo, pp. 470. Price, $5.00.

THIS work was first published in 1848, and, five years later, was rendered into English, with notes and additions, by an American translator. Since its appearance, the subject of which it treats has been rapidly advanced, twenty-five years of observation and active work having added hosts of new facts, and, in many instances, totally changed the interpretation of old ones. Yet the work is now reissued in its old form, without so much as a recognition of later investigations, or of the changes that have taken place in methods of classification. The book is also defective in the total absence of illustrations, which are indispen-

sable to the elucidation of this class of subjects. The publisher assigns, as a reason for its reappearance, that no other work on the subject meets existing requirements. This is a mistake. Both Owen and Huxley are equally eminent authorities in this field, and both have published books on the subject since Siebold—that of Huxley being later by sixteen years.

FREE-HAND DRAWING. By an ART-STUDENT, author of "Ornamental and Figure Drawing." New York: D. Van Nostrand. 18mo, 85 pp. Price, 50 cents.

THIS book is an explanation of the primary principles of drawing. It teaches the student to draw straight and curved lines, to mingle them with effect in shading, and to realize the results of varying the direction lines in perspective. It also gives him some hints on studying from Nature, and is, in every thing, clear, simple, and effective. It is illustrated throughout.

PUBLICATIONS RECEIVED.

Half-Hours with Insects—Part III. By A. S. Packard, Jr. Boston: Estes & Lauriat. 31 pp. Price, 25 cents.

Coal, as a Reservoir of Power, by Robert Hunt, F. R. S.; and Atoms, by Prof. Clifford, M. A. No. 2, Half-Hour Recreations in Popular Science. Boston: Estes & Lauriat. 39 pp. Price, 25 cents.

The Conditions of the Conflict. Oration before the Medical Society of Kings County, N. Y. By Alexander Hutchins, M. D. New York: George F. Nesbitt & Co. 32 pp.

Kindergarten Toys, and how to use them. By Heinrich Hoffman. New York: E. Steiger, 1874. 33 pp. Price, 20 cents.

History of the Colored Schools of Nashville, Tenn. Compiled by G. W. Hubbard. Nashville: Wheeler, Marshall & Prince. 34 pp.

On the Modern Hypotheses of Atomic Matter and Luminiferous Ether. By Henry Deacon. London, 1874. 16 pp.

Longevity, or the Relative Viability of the Sexes, etc. By John Stockton-Hough, M. D. Reprinted from the *Medical Record* of June 16 and July 15, 1873. 9 pp.

Annual Report of the Supervising Surgeon of the Marine Hospital Service of the United States. From July 1, 1872, to June 30, 1873. By John M. Woodworth, M. D. Washington, 1873. 8vo, 154 pp.

Observations on the Pathology and Treatment of Cholera. By John Murray, M. D. New York: G. P. Putnam's Sons. 12mo, 58 pp. Price, $1.00.

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MISCELLANY.

The Priestley Celebration at Northumberland.—The proposition for a Chemical Centennial, alluded to in the June number of the MONTHLY, has taken practical shape, and is to be carried out by a meeting or celebration at Northumberland, Pa., beginning on the 31st of July, 1874. A large number of the eminent chemists of the country have united in an invitation to their brethren to participate in the exercises of the occasion, in the belief that it will foster a feeling of fraternity, and afford a fitting opportunity for that interchange of ideas so important to the advancement of science. Prof. H. Carrington Bolton, of the Columbia College School of Mines, is chairman of the general committee having the matter in charge, and any information respecting the arrangements for the meeting may be obtained by addressing him. In a circular issued by this committee, those planning to attend the meeting at Northumberland are requested to send their names to Dr. Robert McCay, of that place, secretary of the *local* committee of which Dr. Joseph Priestley is chairman.

In order to add to the interest of the occasion, a Loan-Exhibition will take place during the meeting, for displaying apparatus, books, manuscripts, etc., etc., belonging to Dr. Priestley, or other objects illustrating the history of chemistry. Gentlemen interested are earnestly requested to contribute any thing in their possession appropriate to this exhibition. It is expected that the exercises will include an address by Prof. Joseph Henry; a sketch of the life and labors of Priestley, by Prof. Henry H. Croft; a review of the century's progress in theoretical chemistry, by Prof. T. Sterry Hunt; a review of the century's progress in industrial chemistry, by Prof. J. Lawrence Smith; and an essay on American contributions to chemistry, by Prof. Benjamin Silliman. Detailed programmes of the exercises will be distributed at the meeting.

Belt's Theory of Cyclones.—In the "Naturalist in Nicaragua," Mr. Belt has the following on the origin of whirlwinds and cyclones: "I am confident that a study of the smaller eddies of air is the proper way to approach the difficult question of the origin of cyclones." The movements of these small whirling masses may be observed from the outside, and their progress traced from the incipient stage to that of dissolution. In the beginning of a whirlwind there is a movement near the surface of the ground of light particles of dust toward a centre, attended or occasioned by a rotary motion of the air. This quickly rises into a whirling column from fifty to a hundred feet or more in height. On the dry hot plains of Central and South America, and of Australia, this phenomenon is of frequent occurrence, and is not unusual in our temperate latitudes in summer. The whirling columns, according to Mr. Belt, differ in diameter from a few feet to many miles, and his opinion is that "there is a complete gradation from the little dust-eddies, through larger whirlwinds and tornadoes, to the awful typhoons and cyclones of China and the West Indies."

In the small whirlwinds which occur over the land, there is no evidence of the condensation of vapor occurring in dry air. But, where the atmosphere is charged with humidity, as over tropical seas, the condensation is great. The notion, therefore, that whirlwinds and tornadoes originate in sudden condensation, Mr. Belt thinks not well founded, the phenomenon being an incident rather than a cause of the movement. Nor is the theory a satisfactory one, that the meeting of conflicting currents of air and consequent condensation give rise to the phenomenon. Attention is directed to the fact that many terrible whirlwinds are dry, and run their course without producing rain or cloud. They originate at or very near the surface of the ground, where the air

becomes intensely heated. "The quivering of the air over hot ground foreshadows the whirlwind as mirage does the simoom, and sultry heat and oppressive calm do the hurricane." In the stratum of heated air next the ground resides the energy which produces the whirlwind. That this, in many instances, is prevented from rising, has been proved by numerous observations. At last the upward tendency becomes so strong that it breaks through the overlying heavier air, and there occurs an upward discharge, followed by all the phenomena of whirlwinds.

Dupuy on the Functions of the Brain.—Dr. Eugène Dupuy, of Paris, has repeated Ferrier's experiments on the brain, with results which do not accord with those of the English physiologist. In the MONTHLY for December last we gave an account of Ferrier's researches, and hence it will suffice to say here that in his experiments stimulation of the superior external convolution of the brain produced movement of the animal's paw; of the mid-frontal region, contraction of the eyelid; of the parietal region, movement of the ear; of the lower frontal and orbital regions, movement of the tongue. He therefore concludes that in these regions there are actual centres for the movements obtained. Dupuy, on the other hand, wherever the electrodes were placed, whether on the frontal, parietal, or orbital convolutions, succeeded only in obtaining, on slight stimulation, movements of the opposite fore-paw, which, on stronger stimulation, extended to the whole of that side of the body. Further, the electrodes applied to the uninjured surface of the dura mater over the convolutions produced the same effect as when placed on the exposed convolutions themselves.

Dupuy was led to suspect that the electrical stimulation might in these cases be so diffused through the whole hemisphere as to affect directly the base of the brain or even the nerves arising there. To ascertain the truth of this matter he laid bare one-half of the brain of a dog, under complete anæsthesia, and applied to the posterior extremity of the hemisphere the nerve of a galvanoscopic frog, duly insulated. The electrodes were then placed on the front of the hemisphere, and movements produced in the opposite fore-paw, the legs of the frog being simultaneously thrown into violent contraction. Upon another dog, under partial anæsthesia, he divided the corpus striatum and optic thalamus on one side, the corpus callosum having previously been cut through. The electrodes were then placed on the convolutions above and behind the Sylvian fissure. With a strong current, not only the fore-leg of the opposite side, but also the hind-leg, exhibited contraction. In another experiment he removed the whole cerebral mass above the pons Varolii, and applied the electrodes to the cut surface; muscular contractions resulted, limited to the fore-limbs, right and left. These results, many times obtained, render it certain, according to Dr. Dupuy, that electrical stimulation, to whatever part of the brain it may be applied, is widely diffused; and that such diffused stimulation, reaching the base, and there affecting the nuclei, the medulla, or the nerves themselves, will explain all the phenomena obtained by Ferrier and by himself on faradizing the convolutions.

The Sponge-Fisheries.—The chief industry of the Sporades Islands, in the Grecian Archipelago, is the sponge-fishery. The yearly average crop of sponges is estimated at £120,000 sterling. The diving-apparatuses used in the fishery are imported exclusively from England and France. Though there is no difference in construction between English and French machines, with regard to the depth they can attain, or the length of time a diver can remain under water, still English apparatus generally proves stronger, and the gears are of superior quality. The air-tubes, however, have hitherto labored under the disadvantage of being heavier than the French, thus impeding the free movements of the diver, the tubes being caught among the rocks. But, samples of French floating tubes having been sent to England, the result has already been a great improvement in the manufacture of the English article. A common fraud practised by traders in rough sponges is to introduce into them a quantity of sand, so as to add to their weight. In order to guard against this, agents are now sent to Rhodes, which is the centre of this commerce, to purchase the sponge

from the divers or owners of diving-apparatus. In this way the article may be got at first hand, without being weighted with sand.

Alligators swallowing their Young.—Colonel Caleb G. Forshey, of the New Orleans Academy of Science, *à propos* of the question whether snakes swallow their young, states that this habit is certainly found among alligators. "That alligators swallow their young," says Prof. Forshey, "I have had ocular demonstration in a single case; and have the universal tradition of negroes and whites in this region of Louisiana, Mississippi, and Texas, that such is their habit. In the winter of 1843–'44, I was engaged making a survey on the banks of the Homochitto Lake. The day was warm and sunny, and, as I halted near the margin of a pond partly dried up, to pick up some shells, I started a litter of young alligators, that scampered off, yelping like puppies, and retreating some twenty yards to the bank of Lake Homochitto. I saw them reach their refuge in the mouth of a five-foot alligator. She evidently held open her mouth to receive them, as, in single file, they passed in beyond my observation. The dam then turned slowly round, and slid down beneath the water, passing into a large opening in the bank, beneath the root of an ash-tree. Doubtless this refuge is temporary, and the young are released at their own or the mother's pleasure."

Le Conte on the Origin of Western Mounds.—Prof. Joseph Le Conte, in the *American Journal of Science*, discusses the origin of the *mounds* with which the prairies near Puget Sound are studded, and from which they get the name of "mound prairies." These mounds are generally three or four feet high, and thirty to forty feet in diameter at the base. There are millions of them, and they stand so thickly as to touch each other at their bases, leaving no level space between. They consist wholly of a drift-soil of earth, gravel, and small pebbles, the intervals being thickly strewed with larger pebbles and small bowlders. The vegetation of the mounds is mostly ferns; the intervals are covered with fine grass only. Some have supposed that they are Indian burial-mounds; others have thought that they are artificial mounds, upon which were built huts of Indian villages. They have also been supposed to be large fish-nests, dating from the period when these prairies were the bottoms of shallow inlets of the sea. The author holds them to be the result of surface-erosion under peculiar conditions. In another part of the State, viz., between the Dalles and the upper bridge of the Des Chutes River, a distance of about thirty miles, the whole country is literally covered with mounds of this kind. Here they vary in *size*, from scarcely detectible elevations, to mounds five feet high and forty in diameter at the base; and in *form* from circular, through elliptic and long elliptic, to ordinary hill-side erosion-furrows and ridges. In *regularity* of size and position there is equal diversity; in some places being as complete as at Mound Prairie, while, in other places, they are of different sizes, and often separated by *wide, pebble-covered spaces*, as if they were but the remnants of a general erosion of the surface-soil. No one, says Prof. Le Conte, can ride over those thirty miles, and observe closely, without being convinced that these mounds are wholly the result of surface-erosion, acting under peculiar conditions. These conditions are, a *treeless country*, and a *drift-soil*, consisting of two layers—a finer and more movable one above, and a coarser and less movable one below. Surface-erosion cuts through the finer superficial layer, into the pebble-layer beneath, leaving, however, portions of the superficial layer as mounds. The *size* of the mounds depends on the *thickness* of the superficial layer; their *shape* depends much on the *slope* of the surface. The process once started, small shrubs and weeds take possession of the mounds, as the better soil, and hold them by their roots, and thus increase their size, by preventing or retarding erosion. The treelessness of Eastern Oregon has been produced gradually, since post-tertiary times, by the increasing dryness of the climate. We may imagine the mounds, therefore, as having been *held by the struggling remnants of a departing vegetation*. At Mound Prairie, however, the treelessness is probably produced by a contrary condition, viz., the extreme *wetness* of these lower level spots in winter.

Here, therefore, the weeds and ferns hold and preserve the mounds, not only as the better soil, but also as the drier spots.

The Value of Vivisections.—Prof. M. Schiff, of Florence, whose vivisections gave rise to the recent controversy on the cruelty of the practice, has published a book, in which he states the results of his experiments. The following quotations from this work will best show whether, as the opponents of vivisection have claimed, experiments of this kind "lead to no useful result," or are to be classed as "acts of needless cruelty." Prof. Schiff has studied the comparative effects of ether and chloroform on the animal economy. Ether, according to him, is preferable to chloroform as an anæsthetic, because etherization, even when pushed to the very last stage of insensibility, is never dangerous to life, so long as one maintains the act of respiration. And even if one presses the inhalation of ether still further, so that the respiratory movements cease, life is never menaced, if, at the moment of the paralysis of the thoracic walls, artificial respiration is immediately commenced. Chloroform has been preferred to ether because it acts more quickly, and its use is more agreeable to some persons. But chloroform has a paralyzing action much greater than that of ether, and, in like manner, has a special influence on the nerves of the heart, and of the vessels. If the inhalation of chloroform is carried so far as to produce a considerable weakening of the respiratory movements, the interruption of the inhalation may, in a majority of cases, lead to the reëstablishment of respiration, and, afterward, of sensation; but sometimes, in a few moments after the commencement of inhalation, the force of the circulation is so enfeebled that the blood passes sluggishly through the lungs, and its rate of renewal or revivification is much diminished. The blood in the body no longer comes into necessary contact with the atmospheric air introduced by respiration into the lungs. If the action of chloroform is prolonged until respiration ceases, we are not even sure of being able to revive the person, after having reëstablished the respiratory movements; for these often again cease, owing to the disturbance of the circulation, while these same movements, if restored after the inhalation of ether, become always more frequent in the patient when left to himself. Prof. Schiff affirms that, in the present state of science, the medical man *is responsible for every case of death occasioned by the application of ether*, because a careful watching of the respiration is capable of preventing death, while the fatal effect of chloroform depends, in part, on individual predisposition, which the physician is unable to recognize.

Animals and Fire-arms.—That crows and many other species of birds have little fear of man when he is unarmed is a familiar fact, and suggests that they fear him chiefly because of the weapons he carries. In Scotland, where shooting was prohibited on Sunday, crows and rooks were gentle, and fed around buildings without concern. Singularly enough, the same thing was observed of animals by Dr. Tristram when traveling in the wilderness of Moab, where the sound of a gun is quite rare. He says: "We were struck with the sagacity which all the wild animals showed in the matter of fire-arms, little familiar as they can be with them here. As it was Sunday, we strolled or sat down among the ruins without our fowling-pieces, and were consequently objects of indifference. A fine fox sat and looked at us a dozen times among the stone-heaps, and just walked away, keeping almost within gunshot all the afternoon. The Sakkr falcon sat calmly on his favorite perch, and allowed us to reconnoitre him on Sunday, while the eagle, owls, sand-grouse, and partridge, showed a similar contempt for unarmed Europeans."

The Temperature of the Ocean.—Dr. Carpenter recently delivered a lecture before the London Royal Institution, on the "Temperature of the Ocean," showing, from the soundings made by the Challenger Expedition, that the difference of climate between Northwestern Europe and the North American Atlantic seaboard is due not to the course of the Gulf Stream, but to the circulation of the waters of the Ocean between the poles and the equator. The shores of Northwestern Europe have the benefit of the northward movement of the warm superfi-

cial stratum, while the temperature of the American coast is lowered by the surging up against it of deep glacial underflow. The fact, he says, comes out most clearly from the Challenger soundings, which had been suspected by the United States Coast Surveyors, that the cold band which separates the Gulf Stream from the United States coast is really continuous with the cold strata that lie at some depth beneath the Gulf Stream, and this continuity explains the presence of the cold band which was previously wanting. For, as any flow of water from the equator toward either pole will tend toward the east in virtue of the excess of easterly momentum it brings from a part of the globe where its rotation was rapid; so any flow of water proceeding from either pole toward the equator will tend toward the west, in virtue of that deficiency of easterly momentum which it derives from a part of the globe where its rotation was less rapid. In this surging upward of the deeper and colder stratum lying beneath the Gulf Stream, we have very distinct evidence of its southerly movement. The precisely similar cold band which has been observed by Captain St. John to separate the Kuro Liwo, or warm Japan current, from the coast, may be fairly attributed to the same cause.

Action of Frost on the Position of Trees.—The elevation of the trunks of trees was the subject of some observations by Mr. Thomas Mechan at a recent meeting of the Philadelphia Academy of Sciences. On a previous occasion he had attributed this elevation to the natural thickening of the roots, which brought them in contact with unyielding rock beneath, the necessary consequence being that they would then lift the entire tree. Since that time he has been led to offer another explanation, viz., the action of frost. Most trees standing by themselves, he observed, have the collar of much greater diameter than the trunk above, and the upper portions of the roots, springing from about the collar, are considerably above the surface of the ground. That this is caused by the action of frost is rendered probable by what we know of its action on minor vegetation, what is called "drawing out." When the land freezes, expansion ensues, drawing up with it the roots of clover, and leaving of course a cavity from which the root was drawn. At the first thaw the liquid, carrying earthy matter, enters the cavity, and then the clover-root is prevented from descending to its original position. The same is true of trees. Roots, heaved up by frost, find the cavity beneath partially filled, and hence the tree will stand a little higher than before. Dr. Latham, State Botanist of Wisconsin, is of the opinion that large trees blow over much more readily than younger ones with the same proportional weight of head to development of roots, chiefly because the older trees have been drawn nearer to the surface. One of the chief offices of the tap-roots is probably to prevent the tree being lifted too high by the frost. Dr. Meehan is inclined to think that the trees of tropical climates have by no means so great a development of tap-roots as those of more northern regions. This question he proposes to investigate further.

Topography of the Bed of the Pacific.—Soundings made by the United States Steamer Tuscarora, between San Diego, Cal., and Honolulu, S. I., show this part of the Pacific to be a basin with precipitous sides and a comparatively level bottom. In the first 100 miles west from San Diego, there appear to be two valleys and two peaks. The first valley is from 622 to 784 fathoms deep, the first peak 445 fathoms, the second valley 955 fathoms, and the second peak 566 fathoms. Thence a precipitous fall takes place, giving, in latitude 31 °43′ north, longitude 119° 28′ west (Greenwich), 115 miles from San Diego, a depth of 1,915 fathoms. After that there is a gentle slope, with comparatively unimportant interruptions, at the rate of three feet to the mile, to the point of greatest depth, 3,054 fathoms, at a distance of about 400 miles east of Honolulu. The sharpest elevation is a rise about midway between the United States and the Sandwich Islands, in latitude 26° 30′ north, longitude 127° 37′ west, the highest portion of which is 2,159 fathoms below the surface. At the next cast of the lead the valley to the west of this elevation took 2,650 fathoms. The fall of the side of the basin, east of Honolulu,

is even more remarkable than the descent off the American coast. Fifty miles from Honolulu soundings gave 498 fathoms; 40 miles farther east, in latitude 21° 43′ north, longitude 156° 21′ west, the depth was 3,023 fathoms. Between the last-mentioned point and that of greatest depth a hill rises, on whose summit there are only 2,488 fathoms of water.

The Origin of Hair-Snakes.—Dr. Slack, in the *Turf, Field, and Farm*, satisfactorily answers the question put by a correspondent, as to the origin of the so-called hair-snake or hair-worm. The common belief is that these creatures are a transformation of a horse-hair that has remained for some time in water. "When a walking-stick," says Dr. Slack, "becomes a snake, a horse-hair will become a worm. As the former miracle has not taken place since the departure of the Israelites from Egypt, it is safe to conclude that the latter transformation has not recently been made. A dry hair placed in water will absorb the moisture, and, from the unequal expansion of the exterior and interior layers, will become contorted; so too, would a piece of two-inch rope, yet we have never heard of the latter having been accused of possessing vitality. The hair-snake is a living creature, endowed with organs of locomotion and respiration, and capable of propagating its species. Scientifically it is known as *Gordius aquaticus*, the generic name being derived from the Gordian knot, in allusion to the tangled appearance often presented by a multitude of these animals. The specific name *aquaticus* is not so appropriate, for they thrive out of water." Dr. Slack has taken Gordii six inches in length from the body of a grasshopper. They have also been found in the stomachs of insectivorous birds.

Cast and Wrought Iron Stoves.—A commission of the French Academy of Sciences has been investigating the hygienic effects of the use of cast-iron stoves. Experiments were made with stoves of wrought and cast iron, using soft coal, with the view of learning under what conditions stoves of metal became unhealthy, through the presence of carbonic acid and carbonic oxide, in the rooms heated by them. Rabbits were made to breathe the air passing over stoves of cast and wrought iron heated to redness, and afterward the blood of the animals was chemically examined, to ascertain the presence of carbonic oxide. The report states that, though the results of experiments made upon rabbits do not enable us to fix with precision the proportion of carbonic oxide absorbed by their blood, nor that of the oxygen which has been expelled from it, still they show that the use of cast-iron stoves, at a red heat, causes in the blood, by the presence of carbonic oxide, a gas eminently poisonous, changes whose repetition may become dangerous; while the same method of investigation has not revealed analogous effects from stoves of wrought-iron. In summing up the results of the entire series of experiments the commission reports as follows:

"The carbonic oxide, whose presence has been proved when stoves of cast iron are used, may arise from several different causes: 1. The permeability of the stove by that gas, which will pass from the interior of the fire-pot to the exterior. 2. The direct action of the oxygen of the air upon the carbon of the cast-iron heated to redness. 3. The decomposition of carbonic acid contained in the air by its contact with metal heated to redness. 4. The influence of the organic dust naturally contained in the air." The commission recommend that all stoves and heating apparatus of cast-iron, and even of wrought-iron, be lined with fire-brick, or other substance, so as to prevent their attaining a red heat.

South-Sea Surgery.—In some of the South-Sea Islands a method of surgical treatment is adopted in certain cases which would bear away the palm, as a torturing process, even from the dreaded *moxa*. The following description of the South-Sea operation is from the London *Medical Times*: "The wise men in these islands have invented a theory that headache, neuralgia, vertigo, and other affections of the head, arise from a crack in the skull, or from pressure of the skull upon the brain. The remedy which they have contrived consists in laying open the scalp by a T-shaped incision, and then gently scraping away the cranium itself with a piece of glass until the *dura mater*

is reached, and a hole is made in the skull as large as a silver dollar. Of course, if the operation is carried a little too far, the patient dies; and this appears to be the mode in which most of the cures are effected, death being the result in about half the cases operated upon. The hole is usually covered with a piece of cocoa-nut shell, scraped thin, and placed under the scalp. Formerly, the instrument employed was a shark's tooth, but broken glass is found to act better. Bone-scraping is also resorted to as a cure for rheumatism in old people. The skin is cut open, so as to lay bare the bone supposed to be affected, and the surface of the latter is then scraped until a portion of the external lamina is removed. Here surely the remedy is worse than the disease."

New French Life-saving Raft.—An extraordinary safety-raft has recently been invented in France. It is described as large enough to support from 400 to 600 persons, as neither incumbering nor requiring any alteration in the arrangement of vessels, and as needing only a minute or two to inflate and launch it. It is an air-tight mattress, with a surface of nearly 900 square feet, inflated in one minute, it is said, from a reservoir fixed in the engine-room, and always charged with air under a pressure of fifteen atmospheres. When not in use it is rolled up, and takes no more room than a boat. When inflated it falls over the side of the vessel, against which it is retained by ropes till all the persons on board are transferred to the raft. Three strong spars, passing through the whole length of the raft, keep it flat and solid.

Training Shepherd-dogs.—Sheep-raisers in California have an ingenious system for training dogs to guard their flocks. In Southern California one may wander for miles, and see thousands of sheep without a single shepherd to watch them, but around each flock half a dozen dogs. These have the entire care of the sheep, drive them out to pasture in the morning, keep them from straying during the day, and bring them home at night. These animals have inherited a talent for keeping sheep, and this talent is cultivated in the following way: When a lamb is born, or the shepherds have a pup which they want to train, the lamb is taken from its mother, she not being allowed to see her offspring, and the puppy is put in its place, and the sheep suckles it. When the puppy grows old enough to eat meat, it is fed in the morning and sent out with the sheep. It stays with them, because it is accustomed to be with its foster-mother; but it cannot feed with them, and, as they get full, the dog grows hungry. At length, impatient to return, in hopes to get its meat, the dog begins to tease and worry the mother, and finally starts her toward home; the others follow, and thus the whole flock is brought in. If they are brought home too early, or the dog comes without them, he gets punished in some way; and thus, by taking advantage of their instincts and appetite, these dogs are trained to a great state of perfectness, and become invaluable to the owners of large flocks.

Legislative Blunders.—The *Pall Mall Gazette* thus indicts the English Public Health Act of 1872: "Its failure, now that this has become too clear to be disputed, turns out to be of a more than usually instructive kind; for it shows that, contrary to all expectation and probability, there was, in 1872, still a blunder remaining for us to commit in sanitary administration, and that we have since committed it. We had already exhausted every source of administrative inefficiency which is to be found in inadequacy of powers, defects of initiative, and obscure intricacy of law. We had set up sanitary authorities who could not act, authorities who would not act, and authorities who did not know when, where, and how to act: it remained for us to establish authorities who could and must act, and then to misdirect and mislead them into a confusion worse than inactivity. Having failed in every possible way at the circumference, we had yet to fail at the centre, and we have done it."

Skunk-Madness.—Rev. Horace C. Hovey, in the *American Journal of Science*, gives some novel results of a protracted inquiry concerning the common skunk (*Mephitis mephitica*). He says that, at times when

the animal is unable, either from exhaustion or other reasons, to produce that secretion whose stench is its great defense, its bite is productive of a highly-dangerous rabies, often causing death with some of the terrible symptoms of hydrophobia. We have thus authenticated the fact that rabies, capable of being given by the inoculation of a bite, is communicable by the canines, felines, and the mustelidæ families.

How Plants Imbibe Ammonia.—From a series of experiments made by Adolf Mayer, it appears that plants have the power of absorbing ammonia through their aërial parts. The experiments were made on plants growing in such a manner that no ammonia could reach their roots directly, while the leaves were subject to its action, in either a gaseous or dissolved condition. It was observed, however, that the plants did not thrive when the access of ammonia to the roots was entirely prevented.

Reproduction of Organs in Fish.—Darwin, in his "Animals and Plants under Domestication," states, on the authority of Frank Buckland, that, when portions of the pectoral and tail-fins of various fresh-water fish are cut off, they are perfectly reproduced in about six weeks. This phenomenon of regeneration was recently observed in the aquarium of the Boston Young Men's Christian Union, by F. W. Clark, who communicates to the *American Naturalist* an interesting note on the subject. It appears that, in the spring of 1873, a fish-fungus made its appearance in the tank, and several fine fishes died. Among the specimens attacked by the fungus was a young goldfish, which, by some unknown means, had lost its tail-fin. The fungus covered the whole stump of the tail; the fish became sick, and was apparently dying. Mr. Clark's attention having been called to the case, he at once concluded that he had some parasite to deal with, and resolved to exterminate it. He applied a few drops of nitric acid to the tail-stump, allowing it to remain a moment or two, after which he rinsed it off in clean water, and put the fish back in the tank. The parasite, of course, was killed; the patches of fungus sloughed off, and the fish was soon well. In the course of a few days, he thought he saw the fungus again appearing on the affected part; but, on looking closely, found that the appearance was really due to the growth of new rays. A month later, a new tail-fin, about a fourth of an inch long, had appeared, and, three months from the time of the experiment, the fish was undistinguishable from others of the same species in the aquarium.

NOTES

The American Association for the Advancement of Science will hold its twenty-third annual meeting this year at Hartford, commencing at ten o'clock, on Wednesday, August 12th. Members must furnish the permanent secretary, F. W. Putnam, Salem, Mass., with complete titles of all the papers they propose to present during the meeting, together with an estimate of the time required for reading each paper. Each title must be given on a separate slip of paper, with the full name of the author. The titles must be furnished to the secretary before the day appointed for the Association to convene. The Association will at this meeting accept the act of incorporation, giving it a legal existence. Another matter to come before it for deliberation will be the new constitution. From the *American Naturalist* we learn that a monograph on "Fossil Butterflies," by Mr. Scudder, is soon to be published by the Association, the necessary funds having been voted by the committee on Mrs. Thompson's gift. The officers elected for the Hartford meeting are the following: *President*, Dr. J. L. Le Conte, Philadelphia; *Vice President*, Prof. C. S. Lyman, New Haven; *Permanent Secretary*, F. W. Putnam, Salem, Mass.; *General Secretary*, Dr. A. C. Hamlin, Bangor; *Treasurer*, William S. Vaux, Philadelphia.

A correspondent of *Land and Water* relates an instance of a brood of chickens being cared for by a cat. This brood, having been hatched very early in the season, was taken from the hen and placed in a basket near a kitchen fire. Soon the chicks were missing, and, on search being made, were found in an up-stairs room, kindly tended by the domestic cat, being huddled close to her warm fur. They were returned to the kitchen, and, the cat still claiming them, she was left in possession of her adopted brood, which she raised to chickenhood. As they grew up the cat would accompany them in their out-of-door rambles, lying in the sun, and fondly watching them.

Good results have been obtained in the utilization of sewage at Dantzic. The land

on which it is applied is nearly pure sand, and the yield of the sugar-beet grown on it is described as enormous, while the percentage of sugar is equal to that obtained from roots grown on the best soil in Germany. The decrease of the death-rate of the town is considerable, and the "waste" lands have been made to yield remunerative crops.

THE forty-fourth annual meeting of the British Association for the Advancement of Science will be held at Belfast, commencing Wednesday, August 19, 1874. Prof. Tyndall will preside. In 1875, the Association meets at Bristol.

THE annual wine production of the United States is estimated, in round numbers, at 20,000,000 gallons, and the market value at 14,000,000 dollars. The wine production of various States is as follows: California, 5,000,000 gallons; Ohio, 3,500,000; New York, 3,000,000; Missouri, 2,500,000; Illinois, 2,500,000; Pennsylvania, 2,000,000; Iowa, 400,000, and so on downward.

THE *Lancet* expresses the opinion that oftentimes, in fatal explosions of petroleum, death is produced instantaneously by shock, combustion, and anæsthesia. Petroleum is a mixture of homologues belonging to the marsh-gas family, which for many years have been recognized as powerful anæsthetics. Some fifteen years ago an attempt was made to introduce one of them, the hydrid of amyl, as a substitute for chloroform.

IN Corsica the octopus is an esteemed article of food, in fact, a "great delicacy." It is first boiled, and then roasted.

WE are pleased to learn that Mr. J. P. Lesley has been appointed geologist-in-chief to conduct a new survey of the State of Pennsylvania. The results of this survey, as has been pointed out by Mr. MacFarland in a memorial to the Pennsylvania Legislature, cannot fail to be exceedingly important. A more competent man than Mr. Lesley could not have been found for the office of chief geologist.

THE Royal Agricultural Society of England has made a grant of £100 to Prof. De Bary, of Strasburg, to enable him to make a special investigation into the life history of the potato fungus, *peronospora infestans*.

THE third meeting of the French Association for the Advancement of Science opens at Lille, on the 20th of August, continuing till the 27th. Prof. Ad. Wurtz, the distinguished chemist, is president of the Association for the current year. The local committee includes the chief notabilities of Lille and of the Department du Nord.

ANOTHER new artificial stone, according to the *Mining and Scientific Press*, has lately been brought out in California. The process of manufacture is not given, but it is said to be simple and cheap. The stone is impervious to moisture, fire-proof, and presents a fine appearance. It may be manufactured on the spot where it is wanted for use, and, requiring no subsequent handling, blocks of any size can be employed.

WITH the present year the series of annual international exhibitions at South Kensington, London, will cease. According to *Iron*, the undertaking appears to have been *managed* to death, the meddlesome tinkering of the commissioners having driven otherwise well-disposed manufacturers and tradesmen out of the exhibitions.

M. PLANCHON, with whose labors our readers are familiar, has succeeded in tracing directly to an importation of American vines into France, in 1862, the Phylloxera pest now ravaging the vineyards of that country. He has found at Roquemare a plantation of 154 American stocks, which dates from that year. All the other vines in the neighboring districts have been nearly destroyed, while these American stocks are intact. Though their roots are covered with the parasite, their foliage and fruit are very good. It was at Roquemare that the grape-vine disease first made its appearance in 1863, and then extended in every direction. It begins to be admitted now in France that the only protection against the Phylloxera is to be found in the introduction of American vines.

ARTICLES on which flour-paste has been used are often injured by rats, even after the paste has become dry and hard. This can be prevented by mixing a small quantity of corrosive sublimate with the paste. Those who have tried this pronounce it harmless to persons handling it, and a complete safeguard against the rats.

IN his work on the "Influence of Forests," Ebermayer gives a table of observations showing the temperature of the earth covered by snow during the extremely cold weather of December, 1871. He states that on the 8th and 12th of December, 1871, the temperature of the air fell to 26.8° Fahr., while the temperature of the earth beneath the snow was no lower than 33.8°, and four feet below it was 42.8°.

THE seventh meeting of the International Congress of Prehistoric Archæology and Anthropology, will open at Stockholm on Friday, August 7, 1874, and will continue till Sunday, August 16th. The government of Sweden gives 20,000 francs to defray the expenses of the Congress.

Dr. JOHN L. LE CONTE.